4. What command brings up an interface that previously was administratively disabled?

   a. **no shutdown**
   b. **shutdown**
   c. **enable**
   d. **up**
   e. **no disable**
   f. **disable**

5. Imagine that a PC is attached to the same Ethernet as a router. The PC makes a DNS request for host name Fred, and the PC gets a reply showing IP address 10.1.1.1. What command could be issued on the router to list the information learned in that DNS request and reply?

   a. **show hosts**
   b. **show ip hosts**
   c. **show names**
   d. **None of the above**

6. Imagine that a neighboring router's host name is Hannah. Which of these commands could tell you information about the IOS version on Hannah, without Telnetting to Hannah?

   a. **show neighbor**
   b. **show neighbor Hannah**
   c. **show cdp**
   d. **show cdp Hannah**
   e. **show cdp interface**
   f. **show cdp neighbor**
   g. **show cdp neighbor Hannah**
   h. **show cdp entry hannah**
   i. **show cdp neighbor detail**

7. What CDP command(s) could identify the model of hardware of a neighbor?
   a. **show neighbors**
   b. **show neighbors Hannah**
   c. **show cdp**
   d. **show cdp Hannah**
   e. **show cdp interface**
   f. **show cdp neighbors**
   g. **show cdp entry hannah**
   h. **show cdp neighbors detail**

8. Imagine that you used a **ping** command successfully. What messages would have been sent by the **ping** command?
   a. ICMP ping
   b. ICMP echo request
   c. ICMP echo management
   d. ICMP query

9. Imagine that you just erased all the configuration on a router and reloaded it. To configure the router to use a DNS at IP address 10.1.1.1, which of the following commands is required?
   a. **ip name-server 10.1.1.1**
   b. **ip dns 10.1.1.1**
   c. **ip domain-lookup**
   d. **ip dns-lookup**

10. Imagine that you just logged in to the console of router R1 and then Telnetted to R2. What must you type to suspend your Telnet connection, going back to R1?
    a. suspend
    b. Ctrl-z
    c. Ctrl-Shift-6, then x
    d. quit

The answers to the "Do I Know This Already?" quiz are found in Appendix A, "Answers to the 'Do I Know This Already?' Quizzes and Q&A Sections." The suggested choices for your next step are as follows:

- **8 or less overall score**—Read the entire chapter. This includes the "Foundation Topics" and "Foundation Summary" sections and the Q&A section.
- **9 or 10 overall score**—If you want more review on these topics, skip to the "Foundation Summary" section and then go to the Q&A section. Otherwise, move to the next chapter.

Foundation Topics

Configuring IP Addresses

You easily can configure a Cisco router to forward IP traffic when you understand IP addressing and the IOS configuration process described in Chapter 7, "Operating Cisco Routers." This chapter shows you examples of a variety of commands used to configure and troubleshoot the routing of IP packets in a Cisco router. Tables 13-2 and 13-3 summarize many of the most common commands used for IP configuration and verification.

You can refer to other sources for more information about basic IP configuration on Cisco routers. The Cisco IOS documentation is an excellent reference for additional IP commands (see www.cisco.com/univercd/home/home.htm). Also, the Cisco Press book *Interconnecting Cisco Network Devices* is an excellent reference, particularly if you are not able to attend the instructor-led version of the class. This chapter focuses on the most common commands—the ones most likely to be on the CCNA exams.

Table 13-2 *IP Configuration Commands*

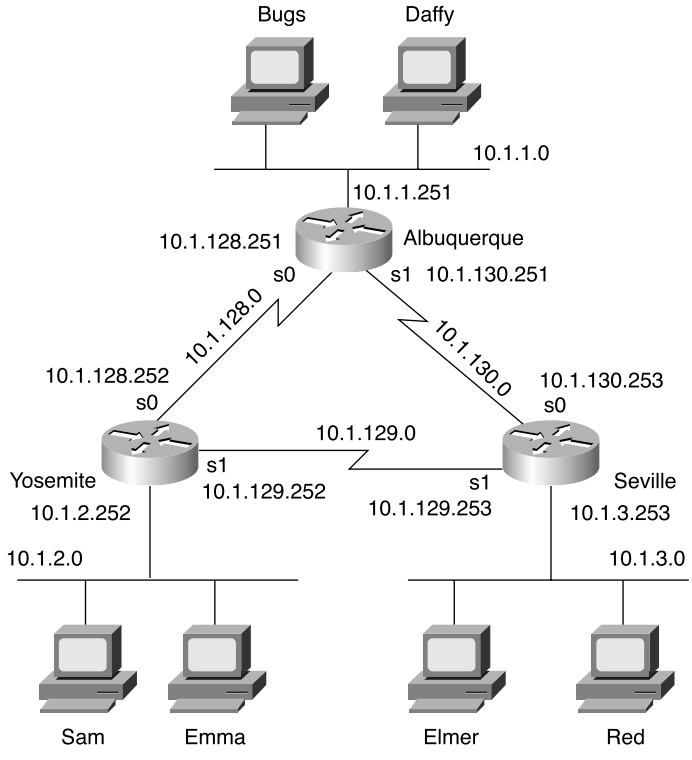
Command	Configuration Mode
ip address *ip-address mask* [**secondary**]	Interface mode
ip host *name* [*tcp-port-number*] *address1* [*address2...address8*]	Global
ip route *network-number network-mask* {*ip-address* | *interface*} [*distance*] [**name** *name*]	Global
ip name-server *server-address1* [[*server- address2*]…*server address6*]	Global
ip domain-lookup	Global
ip routing	Global
hostname *name*	Global
login	Line configuration mode
password *value*	Line configuration mode
enable password [**level** *level*] {*password* | [*encryption-type*] *encrypted-password*}	Global
enable secret [**level** *level*] {*password* | [*encryption-type*] *encrypted-password*}	Global
keepalive [*seconds*]	Interface subcommand
exec-timeout *minutes* [*seconds*]	Line subcommand
logging synchronous	Line subcommand

Table 13-3 *IP EXEC Commands*

Command	Function
show hosts	Lists all host names and corresponding IP addresses
show interfaces [*type number*]	Lists interface statistics, including IP address
show ip interface [*type number*]	Provides a detailed view of IP parameter settings per interface
show ip interface brief	Provides a summary of all interfaces and their IP addresses
show ip route [*ip-address* [*mask*] [**longer-prefixes**]] | [*protocol* [*process-id*]]	Shows entire routing table or a subset if other parameters are entered
show ip arp [*ip-address*] [*host-name*] [*mac-address*] [*type number*]	Displays IP ARP cache
debug ip packet	Issues log messages for each IP packet
terminal ip netmask-format {bitcount | decimal | hexadecimal}	Sets type of display for subnet masks in **show** commands
ping [*protocol* | **tag**] {*host-name* | *system-address*}	Sends and receives ICMP echo messages to verify connectivity
trace [*protocol*] [*destination*]	Sends a series of UDP packets with increasing TTL values to verify the current route to a host

Most of the examples in this chapter refer to the routers in Figure 13-1. The figure shows a simple network with three routers, with each pair of routers having a serial link to the other two routers and a local Ethernet.

Figure 13-1 *Sample Network with Three Routers, with Point-to-Point Serial Links*



Basic Administrative Configuration

Chapter 7 focused on the configuration process more than the actual configuration commands that happened to be in the chapter. Before you configure IP, this short section reviews some of the basic commands you typically will configure on any router.

On most routers, you would configure at least the following:

- A host name for the router
- Reference to a DNS so that commands typed on the router can refer to host names instead of IP addresses
- Set a password on the console port
- Set a password for those Telnetting to the router
- Set the enable secret password to protect access to privileged mode
- Create a banner stating an appropriate warning, depending on the security practices at that company

Example 13-1 shows the output of the **show running-config** command on Albuquerque. The functions described in the list have been configured using the commands that are highlighted in the example.

Example 13-1 *Basic Adminsitrative Settings on Albuquerque Router*

```
Albuquerque#show running-config
Building configuration...

Current configuration : 872 bytes
!
version 12.2
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname Albuquerque
!
enable secret 5 $1$J3Fz$QaEYNIiI2aMu.3Ar.q0Xm.
!
!
ip name-server 10.1.1.100
ip name-server 10.1.2.100
!
interface Serial0
!
interface Serial1
!
interface Ethernet0
!
no ip http server

banner motd ^C
  Should've taken a left turn here! This is Albuquerque...  ^C
!
line con 0
 password cisco
 login
 exec timeout 00
line aux 0
line vty 0 4
 password cisco
 login
loggiing synchronous
```

None of the commands highlighted in Example 13-1 is required for the router to route IP, but the commands are generally useful in real networks. Of note, to make the router ask for a password at the console, you need the **login** console subcommand; the **password** console

subcommand tells the router what password is required at the console. Similar logic applies to the **login** and **password** vty subcommands. And although you do not have to refer to a name server, when you do, you typically refer to at least two because most networks have at least two name servers for redundancy and availability.

When configuring the **enable secret** command, you type the password just like you want the user to type it when logging in to the router; however, the IOS changes the value that is saved in the configuration. For instance, for Example 13-1, I typed **enable secret cisco**, and the router changed cisco to a hashed value that cannot be converted back to cisco.

Two other things that you might want to configure habitually on routers are the console timeout and the synchronization of unsolicited messages. In some cases, you want the router to exit the user from the console after a period of inactivity. In other cases, you do not want the console disabled at all because of inactivity. The **exec timeout** *minutes seconds* command sets the inactivity timeout. Also, unsolicited informational messages and output from the IOS **debug** command both show up at the console by default. These same messages can be seen at the aux port or when Telnetting into a router by using the **terminal monitor** command. The **logging synchronous** line subcommand tells the router not to interrupt the output of a **show** command with these unsolicited messages, letting you read the output of the command that you typed before the router displays the other messages. **logging synchronous** can make your life a lot easier when using a router.

Configuring IP Addresses

Before you configure IP address, you first must decide what IP addresses to configure. Figure 13-1 not only outlined the network diagram, but it also listed the IP addresses chosen for the network. In this case, network 10.0.0.0 hs been subnetted with six subnets and a mask of 255.255.255.0.

After you have chosen the IP addresses and masks, configuration is simple. Examples 13-2, 13-3, and 13-4 show the IP configuration details for the three routers in Figure 13-1. The full configuration for Albuquerque is shown in Example 13-2, with a briefer version of the configs of the other two routers in Examples 13-3 and 13-4.

Example 13-2 *Albuquerque Router Configuration and Exec Commands*

```
Albuquerque#configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Albuquerque(config)#interface serial 0
Albuquerque(config-if)#ip address 10.1.128.251 255.255.255.0
Albuquerque(config)#interface serial 1
Albuquerque(config-if)#ip address 10.1.130.251 255.255.255.0
Albuquerque(config)#interface ethernet 0
Albuquerque(config-if)#ip address 10.1.1.251 255.255.255.0
```

Example 13-2 *Albuquerque Router Configuration and Exec Commands (Continued)*

```
Albuquerque#show running-config
Building configuration...

Current configuration : 872 bytes
!
version 12.2
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname Albuquerque
!
enable secret 5 $1$J3Fz$QaEYNIiI2aMu.3Ar.q0Xm.
!
!
ip name-server 10.1.1.100
ip name-server 10.1.2.100
!
interface Serial0
 ip address 10.1.128.251 255.255.255.0
!
interface Serial1
 ip address 10.1.130.251 255.255.255.0
!
interface Ethernet0
 ip address 10.1.1.251 255.255.255.0
!
no ip http server

banner motd ^C
  Should've taken a left turn here! This is Albuquerque...  ^C
!
line con 0
 password cisco
 login
line aux 0
line vty 0 4
 password cisco
 login
!
end

Albuquerque#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
```

continues

Example 13-2 *Albuquerque Router Configuration and Exec Commands (Continued)*

```
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 3 subnets
C       10.1.1.0 is directly connected, Ethernet0
C       10.1.130.0 is directly connected, Serial1
C       10.1.128.0 is directly connected, Serial0

Albuquerque#terminal ip netmask-format decimal
Albuquerque#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0 255.255.255.0 is subnetted, 3 subnets
C       10.1.1.0 is directly connected, Ethernet0
C       10.1.130.0 is directly connected, Serial1

C       10.1.128.0 is directly connected, Serial0
```

Example 13-3 *Yosemite Router Configuration and Exec Commands*

```
Yosemite#show running-config
Building configuration...

! Lines ommitted for brevity
!
interface Serial0
 ip address 10.1.128.252 255.255.255.0
!
interface Serial1
 ip address 10.1.129.252 255.255.255.0
!
interface Ethernet0
 ip address 10.1.2.252 255.255.255.0
!
! lines ommitted for brevity
```

Example 13-4 *Seville Router Configuration and Exec Commands*

```
Seville#show running-config
! Lines ommitted for brevity
!
!
interface Serial0
 ip address 10.1.130.253 255.255.255.0
!
interface Serial1
 ip address 10.1.129.253 255.255.255.0
!
Ethernet0
 ip address 10.1.3.253 255.255.255.0
!
! Lines ommitted for brevity
```

The **ip address** interface subcommand configures the IP address for each interface, as seen in the highlighted portions of the examples. Because each interface has an IP address, the **interface** configuration command precedes each **ip address** command, identifying to IOS the interface to which the IP address should be assigned. It's that simple!

Prefix Notation

At the end of Example 13-2 (Albuquerque), you also see the results of the **show ip route** command. The output of the command lists the network (10.0.0.0), followed by the notation of /24. This notation, called *prefix notation*, denotes the subnet mask in terms of the number of 1 bits in the subnet mask. The number of bits of value binary 1 in the mask is considered to be the prefix. For instance, mask 255.255.255.0, used in the examples, translates to a prefix of /24 because 255.255.255.0 has 24 binary 1s. Prefix notation is simply a shorter way to write the mask.

If you prefer to see the subnet masks instead of the prefix, simply use the **terminal ip netmask-format decimal** exec command, as shown at the end of Example 13-2. Note that the **show ip route** command issued after the **terminal** command shows the subnet mask instead of the prefix.

Seeding the Routing Table with Connected IP Routes

The Cisco IOS routes IP packets by default—in other words, you do not need to type any commands to tell the router to enable IP routing. Before the router will route packets in or out an interface, the interface must have an IP address, as shown in the earlier examples. So, as configured, each of the three routers can route packets on three different interfaces.

The problem with the configurations shown so far is that the routers do not know routes to all the subnets in the network. The ultimate solution to this problem is to configure a dynamic routing protocol. However, in this chapter, you will learn about how the router learns some routes by virtue of the configuration of IP addresses on the interface. Chapter 14 introduces the different IP routing protocols, and the *CCNA ICND Exam Certification Guide* covers the detailed concepts and configuration for several IP routing protocols.

Routers add routes to their routing tables for the subnets associated with their own physical interfaces. To get a better appreciation of this fact, examine Example 13-5, which shows several commands from the Seville router.

Example 13-5 *Seville Router Routing Table and Interface Status Commands*

```
Seville#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route
Gateway of last resort is not set

10.0.0.0/24 is subnetted, 3 subnets
C       10.1.3.0 is directly connected, Ethernet0
C       10.1.130.0 is directly connected, Serial0
C       10.1.129.0 is directly connected, Serial1

Seville#show ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
Serial0                10.1.130.253    YES manual up                    up
Serial1                10.1.129.253    YES manual up                    up
Ethernet0              10.1.3.253      YES manual up                    up
Yosemite#
Seville#show interface serial 0
Serial0 is up, line protocol is up
  Hardware is HD64570
  Internet address is 10.1.130.253/24
  MTU 1500 bytes, BW 1544 Kbit, DLY 20000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation HDLC, loopback not set
  Keepalive set (10 sec)
  Last input never, output never, output hang never
  Last clearing of "show interface" counters never
  Input queue: 0/75/0/0 (size/max/drops/flushes); Total output drops: 0
  Queueing strategy: weighted fair
  Output queue: 0/1000/64/0 (size/max total/threshold/drops)
     Conversations  0/0/256 (active/max active/max total)
```

Example 13-5 *Seville Router Routing Table and Interface Status Commands (Continued)*

```
     Reserved Conversations 0/0 (allocated/max allocated)
     Available Bandwidth 1158 kilobits/sec
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
     0 packets input, 0 bytes, 0 no buffer
     Received 0 broadcasts, 0 runts, 0 giants, 0 throttles
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
     0 packets output, 0 bytes, 0 underruns
     0 output errors, 0 collisions, 1 interface resets
     0 output buffer failures, 0 output buffers swapped out
     0 carrier transitions
     DCD=up  DSR=up  DTR=up  RTS=up  CTS=up

Seville#show ip interface serial 1
Serial1 is up, line protocol is up
  Internet address is 10.1.129.253/24
  Broadcast address is 255.255.255.255
  Address determined by non-volatile memory
  MTU is 1500 bytes
  Helper address is not set
  Directed broadcast forwarding is disabled
  Outgoing access list is not set
  Inbound  access list is not set
  Proxy ARP is enabled
  Security level is default
  Split horizon is disabled
  ICMP redirects are always sent
  ICMP unreachables are always sent
  ICMP mask replies are never sent
  IP fast switching is enabled
  IP fast switching on the same interface is enabled
  IP Flow switching is disabled
  IP Feature Fast switching turbo vector
  IP multicast fast switching is disabled
  IP multicast distributed fast switching is disabled
  IP route-cache flags are Fast
  Router Discovery is disabled
  IP output packet accounting is disabled
  IP access violation accounting is disabled
  TCP/IP header compression is disabled
  RTP/IP header compression is disabled
  Probe proxy name replies are disabled
  Policy routing is disabled
  Network address translation is disabled
  WCCP Redirect outbound is disabled
  WCCP Redirect inbound is disabled
  WCCP Redirect exclude is disabled
  BGP Policy Mapping is disabled
```

First, here is a quick introduction to the four commands in the example. The **show ip route** command lists routes to the three subnets connected to the Seville router, namely 10.1.130.0, 10.1.129.0, and 10.1.3.0, all with mask 255.255.255.0 (prefix /24). The output from the command lists a C in the first column, which, according to the notes at the beginning of the command output, means "connected." In other words, this router is connected directly to these subnets.

Following the **show ip route** command, the example contains three commands that list information about the interfaces in the router. The **show ip interfaces brief** command lists one line per interface, with IP address information and interface status. Next, the **show interfaces serial 0** command lists more details about a single interface, with most of those details about the interface itself. Finally, the **show ip interfaces serial 1** command shows detailed information about the IP protocol running over interface serial 1.

IOS adds connected routes to the routing table that meet the following requirements:

- The interface has been configured with a valid IP address.
- The interface is in an up and up status according to the various interface-oriented **show** commands.

All three of the **show** commands in Example 13-5 that list interface status information use two designations of up and up. The first status keyword (the first of the two ups in this case) generally refers to OSI Layer 1 status. For instance, if there is no cable plugged in, the first status word would be down instead of up. The second status word generally refers to the status of OSI Layer 2. For instance, if Seville defaulted to use HDLC on serial 0, but Albuquerque configured PPP as the data-link protocol on its serial 1 interface on the other end of the link, the interface status on each end would show up and down.

Another instance in which a router might put an interface in status up and down is when the router does not receive keepalive messages on a regular basis. Cisco routers send, and expect to receive, proprietary keepalive messages on each interface. The purpose of the keepalives is to know whether the interface is usable. For instance, on a point-to-point link between Albuquerque and Yosemite, each router sends a keepalive every 10 seconds. As long as they each receive a keepalive every 10 seconds, they think the link is up and up. If Yosemite did not hear a keepalive for three times the keepalive interval (default 10-second interval, for a total of 30 seconds), Yosemite would put the interface into an up and down status. You can disable keepalives with the **no keepalive** interface subcommand, or you can change the timer with the **keepalive** *interval* interface subcommand.

Those comments aside, as long as an interface status is up and up, the router believes that the interface is usable, so the router can add the associated connected IP route to the routing table.

In some cases, you want an interface to be down for administrative reasons, but you do not want to have to unconfigure it or pull out the cable to keep the interface from being up and up. To bring down an interface for administrative reasons and, as a side effect, remove the connected route from the routing table, you can use the **shutdown** interface subcommand, as shown in Example 13-6.

Example 13-6 *Using the* **shutdown** *Command*

```
Seville#configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Seville(config)#interface serial 1
Seville(config-if)#shutdown
Seville(config-if)#^Z
Seville#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route
Gateway of last resort is not set

10.0.0.0/24 is subnetted, 2 subnets
C       10.1.3.0 is directly connected, Ethernet0
C       10.1.130.0 is directly connected, Serial0

Seville#show ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
Serial0                10.1.130.253    YES manual up                    up
Serial1                10.1.129.253    YES manual Administratively down down
Ethernet0              10.1.3.253      YES manual up                    up

Seville#configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Seville(config)#interface serial 1
Seville(config-if)#no shutdown
Seville(config-if)#^Z
```

In the example, after the **shutdown** command under **interface serial 1**, the route connected to serial 1 (10.1.129.0, mask 255.255.255.0) was removed from the routing table, leaving only two entries. Also, the output of the **show ip interfaces brief** command lists a status of administratively down and down. (The **show ip interfaces** and **show interfaces** commands would show the same status for serial 1.) At the end of the example, the **no shutdown** command brings the interface back up.

Bandwidth, Clock Rate, and Serial Lines in the Lab

As mentioned back in Chapter 4, "Fundamentals of WANs," you can build a WAN link in a lab without using a CSU/DSU. The lab network that I used to build the examples in this chapter used three "back-to-back" serial cables, essentially a DTE and DCE cable pair connected together.

To use a back-to-back WAN connection, one router must supply the clocking. Example 13-7 shows an example configuration for Seville, with a couple of important commands related to WAN links.

Example 13-7 *Seville Router Configuration with* **clock rate** *Command*

```
Seville#show running-config
! Lines ommitted for brevity
!
interface Serial0
 ip address 10.1.130.253 255.255.255.0
 clock rate 128000
!
interface Serial1
 ip address 10.1.129.253 255.255.255.0
 clock rate 128000
 bandwidth 128
!
Ethernet0
 ip address 10.1.3.253 255.255.255.0
!
! Lines ommitted for brevity

Seville#show controllers serial 0/0
Interface Serial0
Hardware is PowerQUICC MPC860
DCE V.35, clock rate 128000
idb at 0x8169BB20, driver data structure at 0x816A35E4
! Lines ommitted for brevity
```

The **clock rate** command sets the rate in bits per second on the router that has the DCE cable plugged into it. In this case, Seville was supplying clocking on both serial interfaces. If no cable has been plugged in, the IOS accepts the command. If a DTE cable has been plugged in, IOS rejects the command. If you do not know which router has the DCE cable in it, you can find out by using the **show controllers** command, as shown at the end of the example. In the example, you can see that the output identifies the type of serial cable.

Also notice the **bandwidth 128** command on serial 1. The **bandwidth** command tells IOS the speed of the link, in kilobits per second, regardless of whether the router is supplying

clocking. The bandwidth setting does not change anything that the router does at Layer 1; instead, this setting is used by IOS software for other purposes. For instance, IGRP and EIGRP both use bandwidth to calculate a metric for routing protocols; they use the bandwidth setting on the interfaces. **bandwidth** defaults to T1 speed on serial interfaces. There is no default for **clock rate**, even with a DCE cable plugged in—it must be configured.

IP Troubleshooting Features

Cisco includes coverage of basic troubleshooting commands and concepts on the CCNA exams. These commands are contained in several places in this book, as well as in the *CCNA ICND Exam Certification Guide*. This section covers some of the tools and commands specific to troubleshooting IP.

Internet Control Message Protocol

Earlier in this chapter, you read about how to configure IP addresses and how to perform some basic troubleshooting. For troubleshooting, you have seen how to look at the routing table with the **show ip route** command, how to look at interface status with several options on the **show interfaces** command, and how to use standard and extended **ping** commands for basic troubleshooting.

TCP/IP includes a protocol specifically to help manage and control the operation of a TCP/IP network, called the Internet Control Message Protocol (ICMP). The ICMP protocol provides a wide variety of information about the health and operational status of a network. *Control Message* is the most descriptive part of the name—ICMP defines messages that helps control and manage the work of IP and, therefore, is considered to be part of TCP/IP's network layer. Because ICMP helps control IP, it can provide useful troubleshooting information. In fact, the ICMP messages sit inside an IP packet, with no transport layer header at all–so it is truly just an extension of the TCP/IP network layer.

RFC 792 defines ICMP and includes the following excerpt, which describes the protocol well:

> Occasionally a gateway (router) or destination host will communicate with a source host, for example, to report an error in datagram processing. For such purposes, this protocol, the Internet Control Message Protocol (ICMP), is used. ICMP uses the basic support of IP as if it were a higher level protocol; however, ICMP is actually an integral part of IP and must be implemented by every IP module.

ICMP uses messages to accomplish its tasks. Many of these messages are used in even the smallest IP network. Table 13-4 lists several ICMP messages.

Table 13-4 *ICMP Message Types*

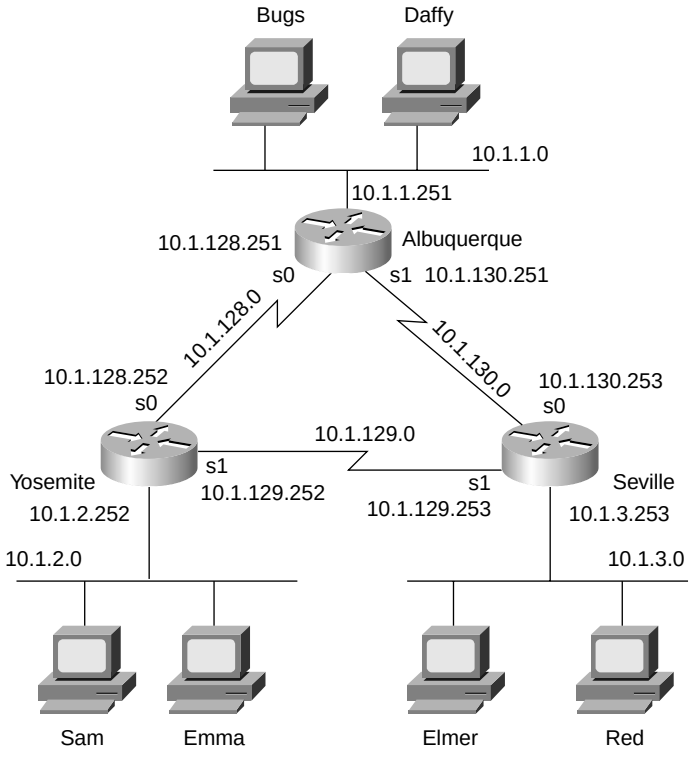
Message	Purpose
Destination unreachable	This tells the source host that there is a problem delivering a packet.
Time exceeded	The time that it takes a packet to be delivered has expired; the packet has been discarded.
Redirect	The router sending this message has received some packet for which another router would have had a better route; the message tells the sender to use the better route.
Echo	This is used by the **ping** command to verify connectivity.

ICMP Echo Request and Echo Reply

The ICMP echo request and echo reply messages are sent and received by the **ping** command. In fact, when people say that they "sent a ping packet," they really mean that they sent an ICMP echo request. These two messages are very self-explanatory. The echo request simply means that the host to which it is addressed should reply to the packet. The echo reply is the ICMP message type that should be used in the reply. The echo request includes some data that can be specified by the **ping** command; whatever data is sent in the echo request is sent back in the echo reply.

Example 13-8 shows two **ping** commands testing IP connectivity from Albuquerque to Yosemite. Figure 13-2 precedes the example, as a reminder of the topology and IP addresses in the network.

Figure 13-2 *Sample Network Used for* **ping** *Example*



Example 13-8 *Example with One Working* **ping**, *and One Failing* **ping**

```
Albuquerque#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 3 subnets

C       10.1.1.0 is directly connected, Ethernet0
C       10.1.130.0 is directly connected, Serial1
C       10.1.128.0 is directly connected, Serial0
Albuquerque#ping 10.1.128.252
Type escape sequence to abort.
```

continues

Example 13-8 *Example with One Working* **ping**, *and One Failing* **ping**

```
Sending 5, 100-byte ICMP Echos to 10.1.128.252, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 4/4/8 ms

Albuquerque#ping 10.1.2.252
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.2.252, timeout is 2 seconds:
.....
Success rate is 0 percent (0/5)
```

The **ping** command sends a packet to the stated destination address. The TCP/IP software at the destination then replies to the ping packet with a similar packet. The **ping** command sends the first packet and waits on the response. If a response is received, the command displays an exclamation mark (**!**). If no response is received within the default timeout of 2 seconds, the **ping** command displays a period (.). The IOS **ping** command sends five of these packets by default.

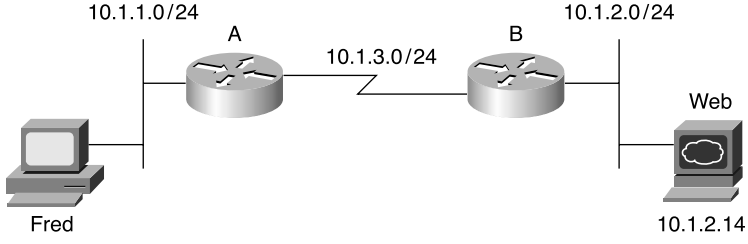
In Example 13-8, the **ping 10.1.128.2** command works, but the **ping 10.1.2.252** command does not. The first **ping** command works because Albuquerque has a route to the subnet in which 10.1.128.2 resides (subnet 10.1.128.0). However, the second **ping** to 10.1.2.252 does not work because the subnet in which 10.1.2.252 resides, subnet 10.1.2.0, is not connected to Albuquerque, so Albuquerque does not have a route to that subnet. So, none of the five ping packets works, resulting in five periods in the output of the **ping** command. (The ping would have worked if a routing protocol had been implemented successfully in this network.) Had these routers been using a routing protocol, the correct routes would have been known, and the second **ping** would have worked.

The **ping** command itself supplies many creative ways to use echo requests and replies. For instance, the **ping** command enables you to specify the length as well as the source and destination addresses, and it also enables you to set other fields in the IP header.

Destination Unreachable ICMP Message

The ICMP Destination Unreachable message is sent when a message cannot be delivered completely to the application at the destination host. Because packet delivery can fail for many reasons, there are five separate unreachable functions (codes) using this single ICMP unreachable message. All five code types pertain directly to an IP, TCP, or UDP feature. The network shown in Figure 13-3 helps you understand them.

Figure 13-3 *Sample Network for Discussing ICMP Unreachable Codes*



Assume that Fred is trying to connect to the web server, called Web. (Web uses HTTP, which in turn uses TCP as the transport layer protocol.) Three of the ICMP unreachable codes can possibly be used by Routers A and B. The other two codes are used by the web server. These ICMP codes are sent to Fred as a result of the packet originally sent by Fred.

Table 13-5 summarizes the more common ICMP unreachable codes. After the table, the text explains how each ICMP code might be needed for the network in Figure 13-3.

Table 13-5 *ICMP Unreachable Codes*

Unreachable Code	When It Is Used	What It Typically Is Sent By
Network unreachable	There is no match in a routing table for the packet's destination.	Router
Host unreachable	The packet can be routed to a router connected to the destination subnet, but the host is not responding.	Router
Can't fragment	The packet has the Don't Fragment bit set, and a router must fragment to forward the packet.	Router

continues

Table 13-5 *ICMP Unreachable Codes (Continued)*

Unreachable Code	When It Is Used	What It Typically Is Sent By
Protocol unreachable	The packet is delivered to the destination host, but the transport layer protocol is not available on that host.	Endpoint host
Port unreachable	The packet is delivered to the destination host, but the destination port has not been opened by an application.	Endpoint host

The following list explains each code in Table 8-8 in greater detail using the network in Figure 13-3 as an example:

- **Network unreachable**—Router A uses this code if it does not have a route telling it where to forward the packet. In this case, Router A needs a route to subnet 10.1.2.0. Router A sends Fred the ICMP Destination Unreachable message with the code "network unreachable" in response to Fred's packet destined for 10.1.2.14.
- **Host unreachable**—This code implies that the single destination host is unavailable. If Router A has a route to 10.1.2.0, the packet is delivered to Router B. However, if the web server is down, Router B does not get an ARP reply from the web server. Router B sends Fred the ICMP Destination Unreachable message with the code "host unreachable" in response to Fred's packet destined for 10.1.2.14.
- **Can't fragment**—This code is the last of the three ICMP unreachable codes that a router might send. Fragmentation defines the process in which a router needs to forward a packet, but the outgoing interface allows only packets that are smaller than the forwarded packet. The router can break the packet into pieces. However, if Router A or B needs to fragment the packet but the Do Not Fragment bit is set in the IP header, the router discards the packet. Router A or B sends Fred the ICMP Destination Unreachable message with the code "can't fragment" in response to Fred's packet destined for 10.1.2.14.
- **Protocol unreachable**—If the packet successfully arrives at the web server, two other unreachable codes are possible. One implies that the protocol above IP, typically TCP or UDP, is not running on that host. This is highly unlikely, because most operating systems that use TCP/IP use a single software package that provides IP, TCP, and UDP functions. But if the host receives the IP packet and TCP or UDP is unavailable, the web server host sends Fred the ICMP Destination Unreachable message with the code "protocol unreachable" in response to Fred's packet destined for 10.1.2.14.

- **Port unreachable**—The final code field value is more likely today. If the server is up but the web server software is not running, the packet can get to the server but cannot be delivered to the web server software. The web server host sends Fred the ICMP Destination Unreachable message with the code "port unreachable" in response to Fred's packet destined for 10.1.2.14.

One key to troubleshooting with the **ping** command is understanding the various codes the command uses to signify the various responses it can receive. Table 13-6 lists the various codes that the Cisco IOS software **ping** command can supply.

Table 13-6 *Codes That the* **ping** *Command Receives in Response to Its ICMP Echo Request*

ping Command Code	Description
!	ICMP Echo Reply received
.	Nothing was received before the **ping** command timed out
U	ICMP unreachable (destination) received
N	ICMP unreachable (network) received
P	ICMP unreachable (port) received
Q	ICMP source quench received
M	ICMP Can't Fragment message received
?	Unknown packet received

IP Naming Commands

When using the IOS CLI, you will want to refer to names instead of IP addresses. Particularly for the **trace**, **ping**, and **telnet** commands, the IP address or host name must be supplied. This section describes the use of host names on an IOS-based device. Along the way, some nuances of the use of Telnet are covered.

IOS can use statically configured names as well as refer to one or more DNSs. Example 13-9 shows some names statically configured, with configuration pointing to two different DNSs.

Example 13-9 *IP Naming Configuration and* **show host** *Command*

```
hostname Cooperstown
!
ip host Mays 10.1.1.1
ip host Aaron 10.2.2.2
ip host Mantle 10.3.3.3
!
ip domain-name gileadfoundation.org
ip name-server 10.1.1.200  10.2.2.200
ip domain-lookup
```

continues

Example 13-9 *IP Naming Configuration and* **show host** *Command (Continued)*

```
Cooperstown#show hosts
Default domain is gileadoundation.org
Name/address lookup uses static mappings

Host                      Flags      Age Type   Address(es)
Mays                      (perm, OK)  0   IP    10.1.1.1
Aaron                     (perm, OK)  0   IP    10.2.2.2
Mantle                    (perm, OK)  0   IP    10.3.3.3
Cooperstown
```

Router Cooperstown will use any of the three statically configured host name–to–IP address mappings. Three names are configured statically in this case—Mays, Aaron, and Mantle. Any command referring to Mays, Aaron, or Mantle will resolve into the IP addresses shown in the **ip host** command.

Router Cooperstown also will ask a DNS for name resolution if it does not know the name and IP address already. The DNS configuration is shown toward the end of the configuration. The IP addresses of the name servers are shown in the **ip name-server** command. Up to six DNSs can be listed; they are searched for each request sequentially, based on the order in the command. Finally, the **ip domain-lookup** command enables IOS to ask a name server. IP domain lookup is the default; **no ip domain-lookup** disables the DNS client function. For names that do not include the full domain name, the **ip domain-name** command defines the domain name that should be assumed by the router.

The **show ip host** command lists the static entries, in addition to any entries learned from a DNS request. Only the three static entries were in the table, in this case. The term **perm** in the output implies that the entry is static. Also note that when short names are used—in other words, the name does not include the DNS domain name—the router adds the domain name of gileadfoundation.org, as configured in the **ip domain-name gileadfoundation.org** command.

Table 13-7 summarizes the key naming commands in IOS.

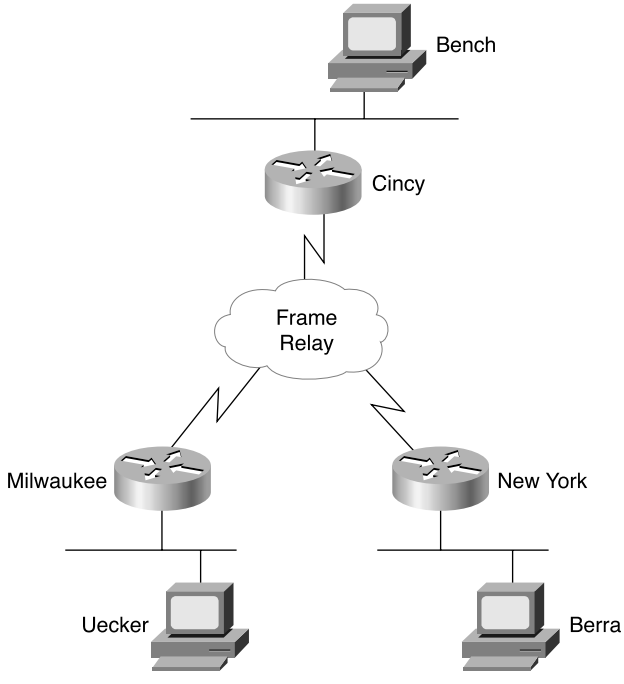
Table 13-7 *IP Naming Commands*

Function	Command Options
Tell IOS to use a DNS	Configure the **ip domain-lookup** global configuration command.
Configure IP addresses of name servers	Configure the **ip name-server** *svr1 svr2...* global configuration command.
Configure static host names	Use the **ip host** *name address* command.
List current host name information	Use the **show hosts** exec command.

Telnet and Suspend

The **telnet** IOS exec command enables you to Telnet from one Cisco device to another; in practical use, it is typically to another Cisco device. One of the most important features of the **telnet** command is the suspend feature. To understand the suspend function, you should to refer to the network diagram in Figure 13-4.

Figure 13-4 *Telnet Suspension*



In the figure, the router administrator is using Bench to Telnet into the Cincy router. When in Cincy, the user Telnets to Milwaukee. When in Milwaukee, the user suspends the Telnet by pressing Ctrl-Shift-6, followed by pressing the letter x. The user then Telnets to New York and again suspends the connection. The example begins with Bench already logged into Cincy. Example 13-10 shows example output, with annotations to the side.

Example 13-10 *Telnet Suspensions*

```
Cincy#telnet milwaukee              (User issues command to Telnet to Milwaukee)
Trying Milwaukee (10.1.4.252)... Open


User Access Verification

Password:                (User plugs in password, can type commands at Milwaukee)
```

continues

Example 13-10 *Telnet Suspensions (Continued)*

```
Milwaukee>
Milwaukee>
Milwaukee>
                          (Note: User pressed Ctrl-Shift-6 and then x)
Cincy#telnet NewYork              (User back at Cincy because Telnet was suspended)
Trying NewYork (10.1.6.253)... Open
                  (User is getting into New York now, based on telnet NewYork command)


User Access Verification

Password:
NewYork>                                  (User can now type commands on New York)
NewYork>
NewYork>
NewYork>
                                       (Note: User pressed Ctrl-Shift-6 and then x)

Cincy#show sessions                (This command lists suspended Telnet sessions)
Conn Host                Address             Byte  Idle Conn Name
   1 milwaukee           10.1.4.252             0     0 milwaukee
*  2 NewYork             10.1.6.253             0     0 NewYork

Cincy#where                           (where does the same thing)
Conn Host                Address             Byte  Idle Conn Name
   1 milwaukee           10.1.4.252             0     0 milwaukee
*  2 NewYork             10.1.6.253             0     0 NewYork

Cincy#resume 1       (Resume connection 1 (see show session) to Milwaukee)
[Resuming connection 1 to milwaukee ... ]

Milwaukee>                             (User can type commands on Milwaukee)
Milwaukee>
Milwaukee>
(Note: User pressed Ctrl-Shift-6 and then x)    (User wants to go back to Cincy)
Cincy#         (WOW! User just pressed Enter and resumes the last Telnet)
 [Resuming connection 1 to milwaukee ... ]

Milwaukee>
Milwaukee>
Milwaukee>
                                  (Note: User pressed Ctrl-Shift-6 and then x)
                                (Tired of Milwaukee again  can't imagine why!)
Cincy#disconnect 1              (No more need to use Milwaukee  Telnet terminated!)
Closing connection to milwaukee [confirm]         (User presses Enter to confirm)
Cincy#
[Resuming connection 2 to NewYork ... ]
```

Example 13-10 *Telnet Suspensions (Continued)*

```
                  (Pressing Enter resumes most recently suspended active Telnet)

NewYork>
NewYork>
NewYork>
                                          (Note: User pressed Ctrl-Shift-6 and then x)
Cincy#disconnect 2                           (Done with New York, terminate Telnet)
Closing connection to NewYork [confirm]             (Just press Enter to confirm)
Cincy#
```

The play-by-play notes in the example explain most of the details. Example 13-10 begins with the Cincy command prompt that would be seen in Bench's Telnet window because the user at Bench Telnetted into Cincy first. After Telnetting to Milwaukee, the Telnet connection was suspended. Then, after Telnetting to New York, that connection was suspended. The two connections can be suspended or resumed easily. The **resume** command can be used to resume either connection; however, the **resume** command requires a connection ID, which is shown in the **show sessions** command. (The **where** command provides the same output.) Also, instead of using the **resume** command, you can just use the session number as a command. For instance, just typing the command **2** does the same thing as typing the command **resume 2**.

The interesting and potentially dangerous nuance here is that if a Telnet session is suspended and you simply press Enter, Cisco IOS Software resumes the connection to the most recently suspended Telnet connection. That is fine, until you realize how much you tend to press the Enter key occasionally to clear some of the clutter from the screen. With a suspended Telnet connection, you also just happened to reconnect to another router. This is particularly dangerous when you are changing the configuration or using potentially damaging exec commands—be careful about what router you are actually using when you have suspended Telnet connections.

If you want to know which session has been suspended most recently, look for the session listed in the **show session** command that has an asterisk to the left of the entry. That session was the most recently suspended session.

Table 13-8 summarizes the commands related to Telnet.

Table 13-8 *Telnet Command Options*

Function	Command Options
Telnet to another device	Use the **telnet** exec command. Just type the host name or IP address from exec mode.
Suspend a Telnet session	Press the key sequence Ctrl-Shift-6, then x.
Discover currently suspended Telnet session	Use the **where** exec command. Use the **show sessions** exec command.
Resume a suspended Telnet session	Use the **resume** command, with no parameter, to reconnect to the most recently suspended Telnet. Use the **resume** *x* command, where *x* is the number of the suspended Telnet session based on the output of **show sessions**. Just press Enter in exec mode to resume to the most recently suspended Telnet session.
Terminate a suspended telnet	Resume connection, and log out using the **quit** command. Use the **disconnect** command on the router you Telnnetted from.

Cisco Discovery Protocol

The Cisco Discovery Protocol (CDP) discovers basic information about neighboring routers and switches, without needing to know the passwords for the neighboring devices. CDP supports any LAN, HDLC, Frame Relay, and ATM interface—in fact, it supports any interface that supports the use of SNAP headers. The router or switch can discover Layer 2 and Layer 3 addressing details of neighboring routers without even configuring that Layer 3 protocol—this is because CDP is not dependent on any particular Layer 3 protocol.

When Cisco first developed the proprietary CDP, it was used mainly between routers. Today most Cisco products support CDP, including Cisco switches and Cisco IP Phones.

Devices that support CDP advertise their own information and learn information about others by listening for their advertisements. On media that support multicasts at the data link layer, CDP uses multicast; on other media, CDP sends a copy of the CDP update to any known data-link addresses. So, any CDP-supporting device that shares a physical medium with another CDP-supporting device can learn about the other device.

CDP discovers several useful details from the neighboring device:

- **Device identifier**—Typically the host name
- **Address list**—Network and data-link addresses
- **Port identifier**—Text that identifies the port, which is another name for an interface
- **Capabilities list**—Information on what type of device it is—for instance, a router or a switch
- **Platform**—The model and OS level running in the device

CDP is enabled in the configuration by default. The **no cdp run** global command disables CDP for the entire device, and the **cdp run** global command re-enables CDP. Likewise, the **no cdp enable** interface subcommand disables CDP just on that interface, and the **cdp enable** command switches back to the default state of CDP being enabled.

A variety of **show cdp** command options are available. Example 13-11 lists the output of the commands, with some commentary following.

Example 13-11 **show cdp** *Command Options*

```
Seville#show cdp ?
  entry      Information for specific neighbor entry
  interface  CDP interface status and configuration
  neighbors  CDP neighbor entries
  traffic    CDP statistics
  |          Output modifiers
  <cr>
Seville#show cdp neighbor
Capability Codes: R - Router, T - Trans Bridge, B - Source Route Bridge
                  S - Switch, H - Host, I - IGMP, r - Repeater

Device ID        Local Intrfce     Holdtme    Capability  Platform  Port ID
fred               Ser 1           172          R        2500      Ser 1
Yosemite           Ser 0.2         161          R        2500      Ser 0.2
Switch             Eth 0           123         S I       WS-C3550-2Fas 0/4

Seville#show cdp entry fred
-------------------------
Device ID: fred
Entry address(es):
  IP address: 163.5.8.3
Platform: cisco 2500,  Capabilities: Router
Interface: Serial1,  Port ID (outgoing port): Serial1
Holdtime : 168 sec

Version :
Cisco Internetwork Operating System Software
IOS (tm) 2500 Software (C2500-DS-L), Version 12.2(3), RELEASE SOFTWARE (fc1)
```

continues

Example 13-11 **show cdp** *Command Options (Continued)*

```
Copyright  1986-2001 by cisco Systems, Inc.
Compiled Wed 18-Jul-01 21:10 by pwade

advertisement version: 2

Seville#show cdp neighbor detail
-------------------------
Device ID: fred
Entry address(es):
  IP address: 163.5.8.3
Platform: cisco 2500,  Capabilities: Router
Interface: Serial1,  Port ID (outgoing port): Serial1
Holdtime : 164 sec

Version :
Cisco Internetwork Operating System Software
IOS (tm) 2500 Software (C2500-DS-L), Version 12.2(3), RELEASE SOFTWARE (fc1)
Copyright  1986-2001 by cisco Systems, Inc.
Compiled Wed 18-Jul-01 21:10 by pwade

advertisement version: 2

-------------------------
Device ID: Yosemite
Entry address(es):
  IP address: 10.1.5.252
Platform: cisco 2500,  Capabilities: Router
Interface: Serial0.2,  Port ID (outgoing port): Serial0.2
Holdtime : 146 sec

Version :
Cisco Internetwork Operating System Software
IOS (tm) 2500 Software (C2500-DS-L), Version 12.2(3), RELEASE SOFTWARE (fc1)
Copyright  1986-2001 by cisco Systems, Inc.
Compiled Wed 18-Jul-01 21:10 by pwade

advertisement version: 2

-------------------------
Device ID: Switch
Entry address(es):
Platform: cisco WS-C3550-24,  Capabilities: Switch IGMP
Interface:     Ethernet0,    Port ID (outgoing port): FastEthernet0/4
Holdtime : 160 sec

Version :
Cisco Internetwork Operating System Software
```

Example 13-11 **show cdp** *Command Options (Continued)*

```
IOS (tm) C3550 Software (C3550-I5Q3L2-M), Version 12.1(11)EA1, RELEASE SOFTWARE
(fc1)
Copyright  1986-2002 by cisco Systems, Inc.
Compiled Wed 28-Aug-02 10:03 by antonino

advertisement version: 2
Protocol Hello:  OUI=0x00000C, Protocol ID=0x0112; payload len=27, value=0000000
0FFFFFFFF010231FF00000000000000000AB7DCB780FF0000
VTP Management Domain: ''
Native VLAN: 1
Duplex: half
Seville#show cdp interface
Ethernet0 is up, line protocol is down
  Encapsulation ARPA
  Sending CDP packets every 60 seconds
  Holdtime is 180 seconds
Serial0.2 is up, line protocol is up
  Encapsulation FRAME-RELAY
  Sending CDP packets every 60 seconds
  Holdtime is 180 seconds
Serial1 is up, line protocol is up
  Encapsulation HDLC
  Sending CDP packets every 60 seconds
  Holdtime is 180 seconds

Seville#show cdp traffic
CDP counters :
        Total packets output: 31, Input: 41
        Hdr syntax: 0, Chksum error: 0, Encaps failed: 9
        No memory: 0, Invalid packet: 0, Fragmented: 0
        CDP version 1 advertisements output: 0, Input: 0
        CDP version 2 advertisements output: 31, Input: 41
```

The commands provide information about both the neighbors and the behavior of the CDP protocol itself. The **show cdp** command has four options, as shown at the beginning of the example. For instace, the **show cdp neighbor** command lists each neighbor, with one line of output per neighbor. Notice that Seville has two router neighbors, denoted by the R, and one switch, in this case a 3550, denoted with an S.

Next in the example, you see two commands that list details per neighbor. The **show cdp entry fred** command lists the details learned by CDP about the neighbor whose host name is fred. (Before using the command, you would just use the **show cdp neighbor** command to find the host names of any neighbors that CDP already has found.) Another command that

lists the detailed information is the **show cdp neighbor detail** command, which is in the same format as **show cdp** entry but lists the information for every neighbor.

You actually can draw a network diagram by using CDP, exercising a little patience, and issuing the right commands on all the devices in a network. Whether you are using the briefer output of **show cdp neighbor** or the more complete output of **show cdp neighbor detail** or **show cdp entry**, the output lists both the local interface and the port ID. The port ID is the interface number, as designated by the other device. For instance, the switch uses port 0/4 to connect to this device. So, you literally could piece together the network diagram from the CDP output.

Foundation Summary

The "Foundation Summary" section of each chapter lists the most important facts from the chapter. Although this section does not list every fact from the chapter that will be on your CCNA exam, a well-prepared CCNA candidate should know, at a minimum, all the details in each "Foundation Summary" before going to take the exam.

The **ip address** interface subcommand assigns an IP address and mask to an interface. If the associated interface is also in an up and up status, the router adds a connected route to the routing table for the subnet connected to that interface. Example 13-12 shows an example configuration with the resulting connected routes.

Example 13-12 *Albuquerque Router Configuration and Connected Routes*

```
Albuquerque#configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Albuquerque(config)#interface serial 0
Albuquerque(config-if)#ip address 10.1.128.251 255.255.255.0
Albuquerque(config)#interface serial 1
Albuquerque(config-if)#ip address 10.1.130.251 255.255.255.0
Albuquerque(config)#interface ethernet 0
Albuquerque(config-if)#ip address 10.1.1.251 255.255.255.0

Albuquerque#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 3 subnets
C       10.1.1.0 is directly connected, Ethernet0
C       10.1.130.0 is directly connected, Serial1
C       10.1.128.0 is directly connected, Serial0
```

Table 13-9 summarizes the key naming commands in IOS.

Table 13-9 *IP Naming Commands*

Function	Command Options
Tell IOS to use a DNS	Configure the **ip domain-lookup** global configuration command.
Configure IP addresses of name servers	Configure the **ip name-server** *svr1 svr2...* global configuration command.
Configure static host names	Use the **ip host** *name address* command.
List current host name information	Use the **show hosts** exec command.

Table 13-10 summarizes the commands related to Telnet.

Table 13-10 *Telnet Command Options*

Function	Command Options
Telnet to another device	Use the **telnet** exec command. Just type the host name or IP address from exec mode.
Suspend a Telnet session	Press the key sequence Ctrl-Shift-6, then x.
Discover currently suspended Telnet session	Use the **where** exec command. Use the **show sessions** exec command.
Resume a suspended Telnet session	Use the **resume** command, with no parameter, to reconnect to the most recently suspended Telnet session. Use the **resume** *x* command, where *x* is the number of the suspended Telnet session based on the output of **show sessions**. Just press Enter in exec mode to resume to the most recently suspended Telnet session.
Terminate a suspended Telnet session	Resume connection, and log out using the **quit** command. Use the **disconnect** command on the router you Telnetted from.

CDP discovers several useful details from neighboring networking devices, including the following. You also should review the actual CDP commands in the chapter and memorize which commands provide which details.

- **Device identifier**—Typically the host name
- **Address list**—Network and data-link addresses
- **Port identifier**—Text that identifies the port, which is another name for an interface
- **Capabilities list**—Information on what type of device it is—for instance, a router or a switch
- **Platform**—The model and OS level running in the device

Q&A

As mentioned in the introduction, you have two choices for review questions. The questions that follow give you a bigger challenge than the exam itself by using an open-ended question format. By reviewing now with this more difficult question format, you can exercise your memory better and prove your conceptual and factual knowledge of this chapter. The answers to these questions are found in Appendix A.

For more practice with exam-like question formats, including questions using a router simulator and multiple-choice questions, use the exam engine on the CD.

1. Create a minimal configuration enabling IP on each interface on a 2501 router (two serial, one Ethernet). The NIC assigned you network 8.0.0.0. Your boss says that you need, at most, 200 hosts per subnet. You decide against using VLSM. Your boss also says to plan your subnets so that you can have as many subnets as possible rather than allow for larger subnets later. When choosing the actual IP address values and subnet numbers, you decide to start with the lowest numerical values. Assume that point-to-point serial links will be attached to this router.
2. In the previous question, what would be the IP subnet of the link attached to serial 0? If another user wanted to answer the same question but did not have the enable password, what command(s) might provide this router's addresses and subnets?
3. What must be done to make the output of the **show ip route** command list subnet masks in decimal format instead of prefixes? In what mode would you use the command?
4. What are the differences between the **clock rate** and **bandwidth** commands?
5. Compare and contrast the commands used to set the enable, console, and telnet passwords on a router.
6. In the output of **show ip route**, when a C shows up in the left side of the output on a line for a particular route, what does that mean?
7. Define the term prefix notation. Give two examples.
8. What does ICMP stand for? To which OSI layer would you consider this protocol to apply most closely?
9. Identify two methods to tell a router to ask for name resolution from two different name servers.
10. What keyboard sequence suspends a Telnet session in a Cisco router?

11. What two commands, and what part the command output, tells you which suspended Telnet connection will be reconnected if you just press the Enter key, without any characters typed on the command line?

12. Imagine that you typed a **ping** command and got 5 "!" back. What type of messages were sent through the network? Be as specific as possible.

13. How do you make a router not ask for DNS resolution from a name server?

14. Imagine that you are just logged in at the console of R1, and you Telnet to routers R2, R3, and R4 in succession, but you suspended your Telnet connection each time—in other words, all three Telnet connections go from R1 to the other three routers, respectively. What options do you have for reconnecting to R2?

15. Imagine that you are just logged in at the console of R1, and you Telnet to routers R2, R3, and R4 in succession, but you suspended your Telnet connection each time—in other words, all three Telnet connections go from R1 to the other three routers, respectively. What options do you have for reconnecting to R4?

16. List the five key pieces of information that can be gathered using CDP, as mentioned in the chapter.

17. Imagine a network with Switch1, connected to Router1, with a point-to-point serial link to Router2, which, in turn, is connected to Switch2. Assuming that you are logged into R1, what commands could be used to find the IP addresses of Router2 and Switch1 without logging in to either device?

18. Imagine that a network with Switch1 is connected to Router1, with a point-to-point serial link to Router2, which, in turn, is connected to Switch2. You can log in only to Switch1. Which of the other devices could Switch1 learn about using CDP? Why?

19. What command lists a brief one-line description of CDP information about each neighbor?

This chapter covers the following subjects:

- Routing Protocol Overview

CHAPTER 14

Introduction to Dynamic Routing Protocols

The United States Postal Service routes a huge number of letters and packages each day. To do so, the postal sorting machines run fast, sorting lots of letters. Then the letters are placed in the correct container and onto the correct truck or plane to reach the final destination. However, if no one programs the letter-sorting machines to know where letters to each ZIP code should be sent, the sorter can't do its job. Similarly, Cisco routers can route many packets, but if the router doesn't know any routes, it can't do its job.

This chapter introduces the basic concepts behind IP routing protocols and lists some of the key features of each of the IP routing protocols covered on the INTRO exam. Cisco expects CCNAs to demonstrate a comfortable understanding of the logic behind the routing of packets and the different but related logic behind routing protocols—the protocols used to discover routes. To fully appreciate the nuances of routing protocols, you need a thorough understanding of routing—the process of forwarding packets. You might even want to review the section "IP Routing and Routing Protocols," in Chapter 5, "Fundamentals of IP," for a review of routing, before proceeding with this chapter.

For those of you studying for the CCNA exam, if you are following the reading plan outlined in the introduction, you will move to the *CCNA ICND Exam Certification Guide* after this chapter. For those of you studying just for the INTRO exam, this chapter completes the coverage of topics related to IP and IP routing.

"Do I Know This Already?" Quiz

The purpose of the "Do I Know This Already?" quiz is to help you decide whether you really need to read the entire chapter. If you already intend to read the entire chapter, you do not necessarily need to answer these questions now.

The eight-question quiz, derived from the major sections in the "Foundation Topics" portion of the chapter, helps you determine how to spend your limited study time.

Table 14-1 outlines the major topics discussed in this chapter and the "Do I Know This Already?" quiz questions that correspond to those topics.

Table 14-1 *"Do I Know This Already?" Foundation Topics Section-to-Question Mapping*

Foundations Topics Section	Questions Covered in This Section
Routing Protocol Overview	1–8

CAUTION The goal of self-assessment is to gauge your mastery of the topics in this chapter. If you do not know the answer to a question or are only partially sure of the answer, you should mark this question wrong for purposes of the self-assessment. Giving yourself credit for an answer that you correctly guess skews your self-assessment results and might provide you with a false sense of security.

1. Which of the following routing protocols are considered to use distance vector logic?
   a. RIP
   b. IGRP
   c. EIGRP
   d. OSPF
   e. BGP

2. Which of the following routing protocols are considered to use link-state logic?
   a. RIP V1
   b. RIP V2
   c. IGRP
   d. EIGRP
   e. OSPF
   f. BGP
   g. Integrated IS-IS

3. Which of the following routing protocols use a metric that is, by default, at least partially affected by link bandwidth?
   a. RIP V1
   b. RIP V2
   c. IGRP

d. EIGRP
e. OSPF
f. BGP
g. Integrated IS-IS

4. Which of the following interior routing protocols support VLSM?
   a. RIP V1
   b. RIP V2
   c. IGRP
   d. EIGRP
   e. OSPF
   f. Integrated IS-IS

5. Which of the following situations would cause RIP to remove all the routes learned from a particular neighboring router?
   a. Keepalive failure
   b. No longer receiving updates from that neighbor
   c. Updates received 5 or more seconds after the last update was sent to that neighbor
   d. Updates from that neighbor have the global "route bad" flag

6. Which of the following interior routing protocols are considered to be capable of converging quickly?
   a. RIP V1
   b. RIP V2
   c. IGRP
   d. EIGRP
   e. OSPF
   f. Integrated IS-IS

7. Which of the following interior routing protocols use hop count as their metric?
   a. RIP V1
   b. RIP V2
   c. IGRP
   d. EIGRP
   e. OSPF
   f. Integrated IS-IS

8. What update timer is used by IGRP?
   a. 5 seconds
   b. 10 seconds
   c. 30 seconds
   d. 60 seconds
   e. 90 seconds
   f. None of the above

The answers to the "Do I Know This Already?" quiz are found in Appendix A, "Answers to the 'Do I Know This Already?' Quizzes and Q&A Sections." The suggested choices for your next step are as follows:

- **6 or less overall score**—Read the entire chapter. This includes the "Foundation Topics" and "Foundation Summary" sections and the Q&A section.
- **7 or 8 overall score**—If you want more review on these topics, skip to the "Foundation Summary" section and then go to the Q&A section. Otherwise, move to the next chapter.

Foundation Topics

To pass the INTRO exam, you need to know some basic information about several IP routing protocols. For the ICND exam, you will need to know distance vector concepts, as well as how to configure two distance vector IP routing protocols—the Routing Information Protocol (RIP) and the Interior Gateway Routing Protocol (IGRP). You will also need to know the concepts behind Enhanced IGRP (EIGRP), as well as Open Shortest Path First (OSPF)—two other IP routing protocols.

This chapter provides overview of routing protocols and the underlying logic used by these protocols.

Routing Protocol Overview

IP routing protocols have one primary goal—to fill the IP routing table with the current best routes it can find. The goal is simple, but the process and options can be complicated.

Terminology can get in the way when you're learning about routing protocols. This book's terminology relating to routing and routing protocols is consistent with the authorized Cisco courses, as well as with most Cisco documentation. So, just to make sure you have the terminology straight before diving into the details, a quick review of a few related terms might be helpful:

- A *routing protocol* fills the routing table with routing information. Examples include RIP and IGRP.
- A *routed protocol* is a protocol with OSI Layer 3 characteristics that define logical addressing and routing. The packets defined by the network layer (Layer 3) portion of these protocols can be routed. Examples of routed protocols include IP and IPX.
- The term *routing type* has been used in other Cisco courses, so you should also know this term. It refers to the type of routing protocol, such as link-state or distance vector.

IP routing protocols fill the IP routing table with valid, (hopefully) loop-free routes. Although the primary goal is to build a routing table, each routing protocol has a very important secondary goal of preventing loops. The routes added to the routing table include a subnet number, the interface out which to forward packets so that they are delivered to that subnet, and the IP address of the next router that should receive packets destined for that subnet (if needed).

An analogy about routing protocols can help. Imagine that a stubborn man is taking a trip to somewhere he has never been. He might look for a road sign referring to the destination town and pointing him to the next turn. By repeating the process at each intersection, he eventually should make it to the correct town. Of course, if a routing loop occurs (in other words, he's lost!) and he stubbornly never asks for directions, he could drive around forever—or at least until he runs out of gas. In this analogy, the guy in the car is like a routed

protocol—it travels through the network from the source to the destination. The *routing protocol* is like the fellow whose job it is to decide what to paint on the various road signs. As long as all the road signs have correct information, the guy in the car should make it to the right town just by reading the road signs. Likewise, as long as the routing protocol puts the right routes in the various routing tables, the routers should deliver packets successfully.

All routing protocols have several general goals, as summarized in the following list:

- To dynamically learn and fill the routing table with a route to all subnets in the network.
- If more than one route to a subnet is available, to place the best route in the routing table.
- To notice when routes in the table are no longer valid, and to remove those routes from the routing table.
- If a route is removed from the routing table and another route through another neighboring router is available, to add the route to the routing table. (Many people view this goal and the preceding one as a single goal.)
- To add new routes, or to replace lost routes with the best currently available route, as quickly as possible. The time between losing the route and finding a working replacement route is called *convergence time*.
- To prevent routing loops.

So, all routing protocols have the same general goals. Cisco IOS Software supports a large variety of IP routing protocols. IP's long history and continued popularity have resulted in the specification and creation of several different competing routing protocol options. So, classifying IP routing protocols based on their differences is useful.

Comparing and Contrasting IP Routing Protocols

Routing protocols can be categorized in several ways. One distinction is whether the protocol is more useful between two companies or inside a single company. Only one IP routing protocol that is popular today, the Border Gateway Protocol (BGP), is designed specifically for use between two different organizations. In fact, BGP distributes routing information between ISPs worldwide today and between ISPs and their customers as need be.

Routing protocols that are best used to distribute routes between companies and organizations, such as BGP, are called *exterior routing protocols*. Routing protocols designed to distribute routing information inside a single organization are called *interior* routing protocols. The comparison is like the U.S. Department of Transportation (DOT) versus the local government's transportation department. The U.S. DOT plans the large interstate highways, but it could care less that someone just sold a farm to a developer and the local government has given the developer the approval to pave a new street so that he can build some houses. The U.S. DOT could be compared to exterior routing protocols—they care about overall worldwide connectivity, but they could care less when a single company adds

a new LAN and a new subnet. However, the interior routing protocols do care, so when the packet gets to the company, all the routers will have learned about any new subnets, and the packet can be delivered successfully.

This section focuses on how to compare the interior IP routing protocols because there are several on the INTRO exam and there are many points of comparison. Table 14-2 lists some of the major comparison points.

Table 14-2 *Major Comparison Points Between Interior Routing Protocols*

Point of Comparison	Description
Type of routing protocol	Each interior routing protocol covered in this chapter can be characterized based on the underlying logic used by the routing protocol. This underlying logic often is referred to as the type of routing protocol. The three types are distance vector, link-state, and hybrid.
Full/partial updates	Some interior routing protocols send their entire routing tables regularly, which are called *full routing updates*. Other routing protocols send only a subset of the routing table in updates, typically just the information about any changed routes. This subset is referred to as *partial routing updates*. Partial routing updates require less overhead in the network.
Convergence	Convergence refers to the time required for routers to react to changes (for example, link failures and router failures) in the network, removing bad routes and adding new, better routes so that the current best routes are in all the routers' routing tables.
Metric	The metric refers to the numeric value that describes how good a particular route is. The lower the value is, the better the route is. Some metrics provide a more realistic perspective on which routes are truly the best routes.
Support for VLSM	*Variable-length subnet masking (VLSM)* means that, in a single Class A, B, or C network, multiple subnet masks can be used. The advantage of VLSM is that it enables you to vary the size of each subnet, based on the needs of that subnet. For instance, a point-to-point serial link needs only two IP addresses, so a subnet mask of 255.255.255.252, which allows only two valid IP addresses, meets the requirements but does not waste IP addresses. A mask allowing a much larger number of IP addresses then can be used on each LAN-based subnet. Some routing protocols support VLSM, and some do not.
Classless or classful	*Classless routing protocols* transmit the subnet mask along with each route in the routing updates sent by that protocol. *Classful routing protocols* do not transmit mask information. So, only classful routing protocols support VLSM. To say that a routing protocol is classless is to say that it supports VLSM, and vice versa.

The next few sections take you through the basics of each of the types of interior routing protocols, as well as give you a short description of each routing protocol.

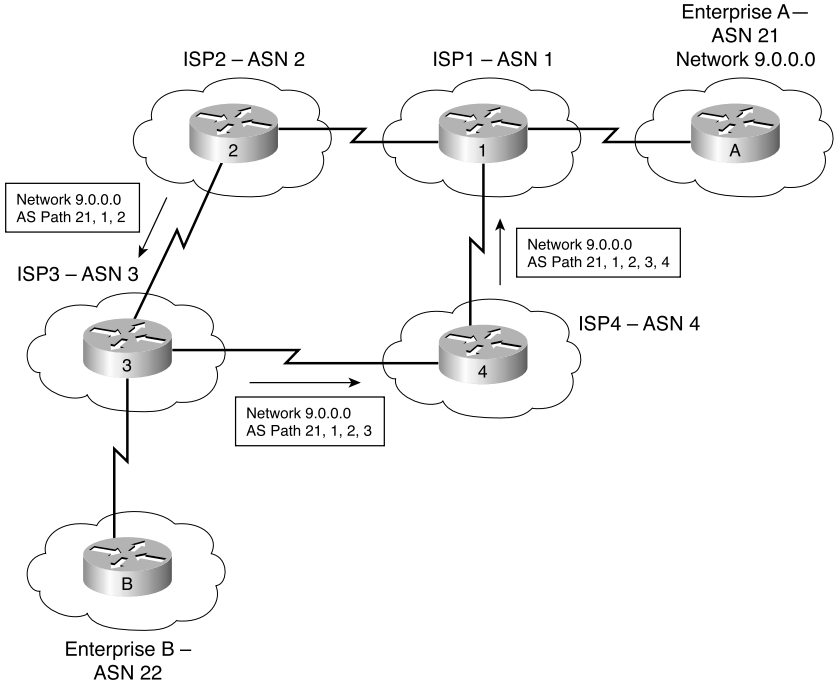
Routing Through the Internet with the Border Gateway Protocol

ISPs use BGP today to exchange routing information between themselves and other ISPs and customers. Whereas interior routing protocols might be concerned about advertising all subnets inside a single organization, with a large network having a few thousand routes in the IP routing table, exterior routing protocols try to make sure that advertising routes reach every organization's network. Exterior routing protocols also deal with routing tables that, with a lot of work done to keep the size down, still exceed 100,000 routes.

BGP advertises only routing information to specifically defined peers using TCP. By using TCP, a router knows that any routing updates will be re-sent if they happen to get lost in transit.

BGP uses a concept called autonomous systems when describing each route. An *autonomous system* (*AS*) is a group of devices under the control of a single organization—in other words, that organization has autonomy from the other interconnected parts of the Internet. An AS number (ASN) is assigned to each AS, uniquely identifying each AS in the Internet. BGP includes the ASNs in the routing updates to prevent loops. Figure 14-1 shows the general idea.

Figure 14-1 *BGP Uses ASNs to Prevent Routing Loops*



Notice that in the figure, the BGP updates sent to each successive AS show the ASNs in the route. When R1 receives the BGP update from R4, it notices that its own ASN in found inside the AS path and ignores that particular route.

BGP does not use a metric like internal routing protocols. Because BGP expects to be used between different ISPs and between ISPs and customers, BGP allows for a very robust set of alternatives for deciding what route to use; these alternatives are called policies. Routing policy can be based on the fact that an ISP might have a better business relationship with a particular ISP. For instance, in Figure 14-1, packets from Enterprise B toward Enterprise A can take the "high" route (from ASN 3, to ASN 2, and then to ASN 1) if ISP3 has a better business relationship with ISP2, as compared with ISP4.

In the next section, you will learn about interior routing protocols and how they use some more obvious metrics.

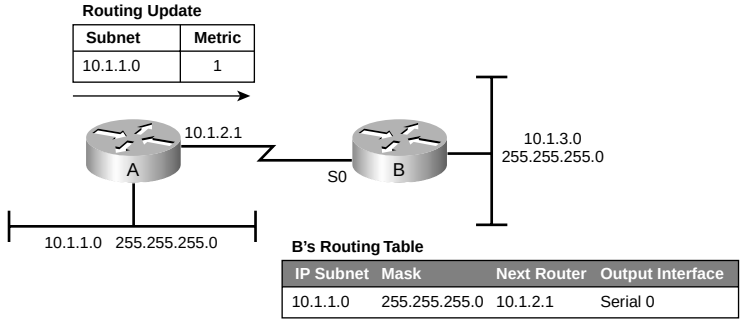
Distance Vector Protocols: RIP and IGRP

Distance vector protocols advertise routing information by sending messages, called *routing updates*, out the interfaces on a router. These updates contain a series of entries, with each entry representing a subnet and a metric. The metric represents how good the route is from that router's perspective, with a smaller number being a better route.

Any routers that receive a copy of a distance vector routing update receive that information and possibly add some routes to their routing table. The receiving router adds the routes only if the routing update described a route to a subnet that it did not already know about or if it described a route that already was known, but the newly learned route has a better (lower) metric.

Figure 14-2 depicts the basic process.

Figure 14-2 *Basic Distance Vector Routing Update, with Resulting Learned Route*



Note that Router A advertises the route to its LAN subnet to Router B. The update includes only the subnet number and a metric. Router B then adds a route to its routing table, but the route has more information in it than did the routing update itself. When B received the update, it came in interface Serial0, so Router B considers Serial0 to be the correct outgoing interface. The update came from IP address 10.1.2.1, so Router B considers that IP address to be the next-hop IP address. Also, if the distance vector update does not include the subnet mask, as in the figure, Router B assumes that Router A uses the same mask that it does. As it turns out, these routers would not support VLSM because if Router A used a different subnet mask than Router B, B would make a wrong assumption about the mask. The fact that the routing protocol in this example does not transmit mask information also makes it a classful routing protocol. For these examples, assume that all routers are using the same subnet mask in this network—specifically, 255.255.255.0.

If it seems simple, then you understand it well—distance vector protocols first were created about 20 years ago, when the processor in a routing device was probably less powerful than the processor in your cell phone today. It had to be simple so as not to overburden the router's processor, and also not to overload the network with overhead traffic.

The following list formalizes the basic distance vector logic and introduces a few important concepts that are explained over the next several pages:

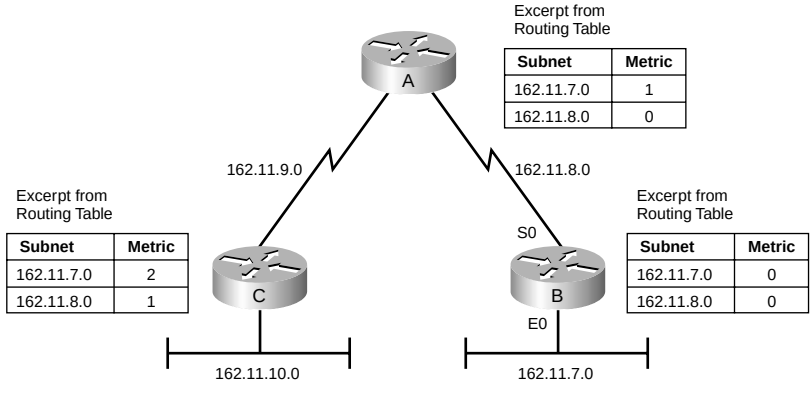
- Routers add directly connected subnets to their routing tables, even without a routing protocol.
- Routers send routing updates out their interfaces to advertise the routes that this router already knows. These routes include directly connected routes as well as routes learned from other routers.
- Routers listen for routing updates from their neighbors so that they can learn new routes.
- The routing information includes the subnet number and a metric. The metric defines how good the route is; lower metric routes are considered better routes.
- When possible, routers use broadcasts or multicasts to send routing updates. By using a broadcast or multicast packet, all neighbors on a LAN can receive the same routing information in a single update.
- If a router learns multiple routes to the same subnet, the router chooses the best route based on the metric. (If the metrics tie, there are a variety of options, which are described in Chapter 6, "OSPF and EIGRP Concepts and Configuration," of the *CCNA ICND Exam Certification Guide*.)
- Routers send periodic full updates and expect to receive periodic updates from neighboring routers.
- Failure to receive updates from a neighbor in a timely manner results in the removal of the routes previously learned from that neighbor.
- A router assumes that, for a route advertised by Router X, the next-hop router in that route is Router X.

Routing Information Protocol Version 1

RIP Version 1 (RIP-1) has been around for a long time—longer than 15 years for use with IP networks. It has many shortcomings compared to some of the relatively newer IP routing protocols, but it does work and is an easy tool to use for comparison with the other routing protocols.

RIP uses hop count for a metric. That means that, from an individual router's perspective, if there are two routers between itself and a subnet, its metric for that subnet is 2. Figure 14-3 outlines the concept.

Figure 14-3 *RIP's Use of Hop Count as Metric*



Only a part of the routing table for each router is shown in the figure, but from those shown, you can see what is meant by the hop count. Router B's metrics for its locally attached subnets are both 0 because there are no routers between B and those subnets. Similarly, Router A's metric for 162.11.8.0 is 0. Because Router B separates Router A from subnet 162.11.7.0, Router A's metric for subnet 162.11.7.0 is 1. Finally, Router C's metric for subnet 162.11.7.0 is 2 because two routers separate it from that subnet.

You will learn much more about RIP and the underlying distance vector logic used by RIP as you prepare for the ICND exam. For now, this short list of RIP-1 features can help you compare RIP-1 to some of the other IP routing protocols covered in this overview:

- Based on distance vector Logic
- Uses hop count for the metric
- Sends periodic full routing updates every 30 seconds
- Converges slowly, often taking 3 to 5 minutes
- Does not support VLSM, also making it a classful routing protocol

RIP Version 2

RIP Version 2 (RIP-2), as currently defined in RFC 2453, defines several enhancements to the original RIP protocol. RIP-2 uses distance vector logic; uses hop count for the metric; sends full, periodic updates; and still converges relatively slowly.

RIP-2 does add support for VLSM, as compared with RIP-1, making it a classless routing protocol, with RIP-2 including the subnet mask for each subnet in the routing updates. Table 14-3 outlines the improvements made to RIP with the creation of RIP-2.

Table 14-3 *Improvements Made to RIP by RIP V2*

Feature	Description
Transmits subnet mask with route	This feature allows VLSM by passing the mask along with each route so that the subnet is defined exactly. It allows VLSM, making RIP-2 a classless routing protocol.
Provides authentication	Both clear text (RFC-defined) and MD5 encryption (Cisco-added feature) can be used to authenticate the source of a routing update.
Includes a next-hop router IP address in its routing update	A router can advertise a route but direct any listeners to a different router on that same subnet.
Uses external route tags	RIP can pass information about routes learned from an external source and redistributed into RIP. Another router then can pass these external tags to that same routing protocol in a difference part of the network, effectively helping that other routing protocol pass information.
Uses multicast routing updates	Instead of broadcasting updates to 255.255.255.255 like RIP-1, the destination IP address is 224.0.0.9, an IP multicast address. 224.0.0.9 is reserved specifically for use by RIP-2. This reduces the amount of processing required on non–RIP-speaking hosts on a common subnet.

The most important feature comparing the two is that RIP-2 supports VLSM. Today, when choosing a routing protocol, RIP-1 would not be the best choice—in fact, the RIP-1 RFC has been designated for historic status. Both protocols work well, but RIP-2 is more functional. If you want a routing protocol that uses a public standard and you want to avoid the complexity of link-state protocols, RIP-2 is your best choice.

Interior Gateway Routing Protocol

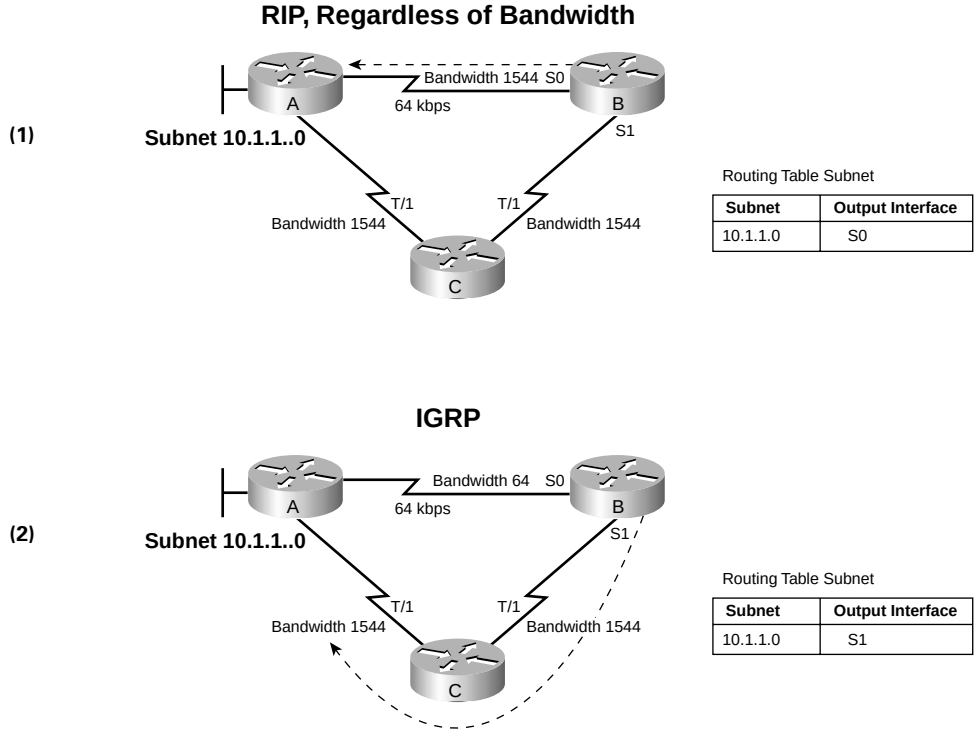
IGRP is a Cisco-proprietary IP routing protocol created by Cisco more than 10 years ago. Cisco created IGRP to provide a better distance vector protocol to its customers, as compared with RIP-1.

The most obvious difference between RIP-1 and IGRP is the metric. IGRP advertises up to five parameters that describe the metric for each route, although, practically, only two ever are used—bandwidth and delay. The bandwidth part of this more complex metric describes the constrained link speed. For instance, if a route to a subnet contained all Fast Ethernet links, the bandwidth in the update would be 100 Mbps; however, if a single 56-kbps link were in the path, the bandwidth would be listed as 56 kbps. The delay component includes a cumulative number—for instance, a route going over ten Fast Ethernet links would have its delay part of the metric ten times bigger than a route with a single 100-Mbps link in the path.

IGRP calculates the metric based on a mathematical formula that you do not really need to know for the exam. The formula uses bandwidth and delay as input and results in an integer value, the metric, between 1 and 4,294,967,295.

Figure 14-4 shows the benefit of this better metric.

Figure 14-4 *RIP and IGRP Metrics Compared*



As shown in the figure, Router B's route to 10.1.1.0 points through Router A because that route has a lower hop count (1) than the route through Router C (2). However, Router B will

choose the two-hop route through Router C when using IGRP because the bandwidths of the two links in the route are much higher than that of the single-hop route. In the top trio of routers, the engineer let the **bandwidth** command default to 1544 on each link because RIP does not consider the bandwidth. On the bottom trio, the engineer correctly configured **bandwidth** to match the actual link speeds, thereby allowing IGRP to choose the faster route. (The **bandwidth interface** subcommand does not change the actual physical speed of the interface–it just tells the IOS what speed to assume the interface is using.)

IGRP and RIP-1 were the main options for routing protocols back in the early 1990s. RIP-2 came later, but only after two better alternatives, OSPF and EIGRP, had become better options for most networks. Table 14-4 summarizes some of the key comparison points between these three protocols.

Table 14-4 *Distance Vector Protocols Compared*

Feature	RIP-1	RIP-2	IGRP
Update timer for full routing updates	30 seconds	30 seconds	90 seconds
Metric	Hop count	Hop count	Function of bandwidth and delay (the default). Can include reliability, load, and MTU.
Supports VLSM	No	Yes	No
Infinite-metric value	16	16	4,294,967,295
Convergence	Slow	Slow	Slow

Link-State Protocols: OSPF and Integrated IS-IS

Link-state and distance vectors share a common goal—to fill the routing tables with the current best routes. They differ significantly in how they each accomplish the task. The largest difference between the two is that distance vector protocols advertise sparse information; in fact, distance vector protocols know only that other routers exist if the other router broadcasts a routing update to them. When a distance vector protocol in a router hears a routing update, the update says nothing about the routers beyond that neighboring router that sent the update. Conversely, link-state protocols advertise a large amount of topological information about the network, and the routers perform some CPU-intensive computation on the topological data. They even discover their neighbors before bothering to exchange routing information.

To figure out the current best routes, a router processes the link-state topology database using an algorithm called the Dijkstra *Shortest Path First (SPF) algorithm*. This detailed topology information, along with the Dijkstra algorithm, helps link-state protocols avoid loops and converge quickly.

Link-state protocols prevent loops from occurring easily because each router essentially has a complete map of the network. If you take a trip in your car and you have a map, you are a lot less likely to get lost than someone else who is just reading the signs by the side of the road. Likewise, the detailed topological information helps link-state protocols easily avoid loops. As you will read later, the main reasons that distance vector protocols converge slowly are related to the loop-avoidance features. With link-state protocols, those same loop-avoidance features are not needed, allowing for fast convergence—often in less than 10 seconds.

Open Shortest Path First

OSPF is the most popular link-state IP routing protocol today and is likely to be the most popular one for some time. It works well, is widely deployed, and includes a wide variety of features that have been added over the years to accommodate new requirements.

The basic operation of OSPF differs from that of the distance vector protocols. For the ICND exam, you will need to know a few more details, of course, but for now, a brief look at how OSPF works will help you compare it with distance vector protocols.

One difference relates to how and when OSPF actually sends routing information. A router does not send routing information with OSPF until it discovers other OSPF-speaking routers on a common subnet. The following list gives you some idea of the process:

1. Each router discovers its neighbors on each interface. The list of neighbors is kept in a neighbor table.
2. Each router uses a reliable protocol to exchange topology information with its neighbors.
3. Each router places the learned topology information into its topology database.
4. Each router runs the SPF algorithm against its own topology database to calculate the best routes to each subnet in the database.
5. Each router places the best route to each subnet into the IP routing table.

Link-state protocols do require more work by the routers, but the work is typically worth the effort. A router running a link-state protocol uses more memory and more processing cycles than do distance vector protocols. The topology updates require a large number of bytes to describe the details of every subnet, every router, and which routers are connected to which subnets. However, because OSPF does not send full updates on a regular short interval (like RIP), the overall number of bytes sent for routing information is typically smaller. Also, OSPF converges much more quickly than do distance vector protocols—and fast convergence is one of the most important features of a routing protocol.

OSPF uses a concept called *cost* for the metric. Each link is considered to have a cost; a route's cost is the sum of the cost for each link. By default, Cisco derives the cost value for a link from the bandwidth, so you can think of the metric as being based on cumulative link bandwidth. (IGRP's metric is based on delay and bandwidth, but it does not treat bandwidth as a cumulative value; it considers only the slowest link in a path.)

The following list points out some of the key features of OSPF:

- Converges very quickly—from the point of recognizing a failure, it often can converge in less than 10 seconds.
- Supports VLSM.
- Uses short Hello messages on a short regular interval (the Hello interval), with the absence of Hello messages indicating that a neighbor is no longer reachable.
- Sends partial updates when link status changes, and floods full updates every 30 minutes. The flooding, however, does not happen all at once, so the overhead is minimal.
- Uses cost for the metric.

Integrated IS-IS

Once upon a time, the world of networking consisted of proprietary networking protocols from the various computer vendors. For companies that bought computers from only that one vendor, there was no problem. However, when you used multiple vendor's computers, networking became more problematic.

One solution to the problem was the development of a standardized networking protocol, such as TCP/IP. Skipping a few dozen years of history, you get to today's networking environment, where a computer vendor couldn't sell a computer without it also supporting TCP/IP. Problem solved!

Well, before TCP/IP became the networking protocol standard solving all these problems, the International Organization for Standardization (ISO) worked hard on a set of protocols that together fit into an architecture called Open System Interconnection (OSI). As you recall from Chapter 2, "The TCP/IP and OSI Networking Models," OSI defined its own protocols for Layers 3 through 7, relying on other standards for Layers 1 and 2, much like TCP/IP does today. OSI did not become commercially viable, whereas TCP/IP did—the victory going to the nimbler, more flexible TCP/IP.

So, why bother telling you all this now? Well, OSI defines a network layer protocol called the Connectionless Network Protocol (CLNP). It also defines a routing protocol—a routing protocol used to advertise CLNP routes, called Intermediate System-to-Intermediate System (IS-IS). IS-IS advertises CLNP routes between "intermediate systems," which is what OSI calls routers.

Later in life, IS-IS was updated to include the capability to advertise IP routes as well as CLNP routes. To distinguish it from the older IS-IS, this new updated IS-IS is called *Integrated IS-IS*. The word integrated identifies the fact that the routing protocol can exchange routing information for multiple Layer 3 routed protocols.

Integrated IS-IS has an advantage over OSPF because it supports both CLNP and IP route advertisement, but most installations could not care less about CLNP. Table 14-5 outlines the key comparison points with all Interior routing protocols for both Integrated IS-IS and OSPF.

Table 14-5 *IP Link-State Protocols Compared*

Feature	OSPF	Integrated IS-IS
Period for individual reflooding of routing information	30 minutes	15 minutes
Metric	Cost	Metric
Supports VLSM	Yes	Yes
Convergence	Fast	Fast

Balanced Hybrid Protocols: Enhanced IGRP

EIGRP does not use distance vector or link-state logic, but instead it uses a whole new category of routing protocol. This new category has some features similar to link-state protocols, others similar to distance vector protocols, and yet others unlike either of the two. Cisco sometimes categorizes EIGRP as a *balanced hybrid protocol*, so you should remember the term.

The internal workings of EIGRP depend on an algorithm called the *Diffusing Update Algorithm (DUAL)*. DUAL exchanges more topology information than a distance vector routing protocol, but it does not transmit full topology information like a link-state protocol. Also, the computations used by DUAL require far less processing than the computation-intensive Dijkstra SPF algorithm.

DUAL defines a method for each router not only to calculate the best current route to each subnet, but also to calculate alternative routes that could be used if the current route fails. An alternative route, using what DUAL calls a *feasible successor route*, is guaranteed to be loop-free. So, if the current best route fails, the router immediately can start using the feasible successor route instead so that convergence can happen very quickly.

The following list points out some of the key similarities to some of the other protocols covered in this introduction:

- Like OSPF and Integrated IS-IS, it converges quickly, often in less than 3 seconds after a failure is recognized.
- Like OSPF, EIGRP discovers neighbors before sending them routing information.
- Like RIP and IGRP, EIGRP requires very little design effort. (Link-state protocols require some design work in medium to larger networks).
- Like IGRP, EIGRP is Cisco proprietary.
- Like IGRP, EIGRP uses a metric based on bandwidth and delay. EIGRP uses the same metric as IGRP, except that EIGRP scales the metric by multiplying by 256.
- Like link-state protocols, EIGRP does not send full updates on a periodic interval, but rather sends partial updates only as links or routers go up and down.
- Like link-state protocols, EIGRP builds some topology tables in addition to the IP routing table.

Summary of Interior Routing Protocols

Before finishing your study for the ICND or CCNA exam, you will learn a lot more about RIP-1, IGRP, EIGRP, and OSPF. This chapter has introduced you to some of the key terms and points of comparison for these routing protocols, as well as a few others. Table 14-6 summarizes the most important points of comparison between the interior routing protocols, and Table 14-7 lists some of the key terminology.

Table 14-6 *Interior IP Routing Protocols Compared: Summary*

Routing Protocol	Metric	Convergence Speed	Supports VLSM and Is a Classless Routing Protocol	Default Period for Full Routing Updates
RIP-1	Hop count	Slow	No	30 seconds
RIP-2	Hop count	Slow	Yes	30 seconds
IGRP	Calculated based on constraining bandwidth and cumulative delay	Slow	No	90 seconds
EIGRP	Same as IGRP, except multiplied by 256	Very fast	Yes	N/A
OSPF	Cost, as derived from bandwidth by default	Fast	Yes	N/A
Integrated IS-IS	Metric	Fast	Yes	N/A

Table 14-7 *Routing Protocol Terminology*

Term	Definition
Routing protocol	A protocol whose purpose is to learn the available routes, place the best routes into the routing table, and remove routes when they are no longer valid.
Exterior routing protocol	A routing protocol designed for use between two different organizations. These typically are used between ISPs or between a company and an ISP. For example, a company would run BGP, an exterior routing protocol, between one of its routers and a router inside an ISP.
Interior routing protocol	A routing protocol designed for use within a single organization. For example, an entire company might choose the IGRP routing protocol, which is an interior routing protocol.
Distance vector	The logic behind the behavior of some interior routing protocols, such as RIP and IGRP.
Link state	The logic behind the behavior of some interior routing protocols, such as OSPF.
Balanced hybrid	The logic behind the behavior of EIGRP, which is more like distance vector than link state but is different from these other two types of routing protocols.
Dijkstra Shortest Path First (SPF) algorithm	Magic math used by link-state protocols, such as OSPF, when the routing table is calculated.
Diffusing Update Algorithm (DUAL)	The process by which EIGRP routers collectively calculate the routes to place into the routing tables.
Convergence	The time required for routers to react to changes in the network, removing bad routes and adding new, better routes so that the current best routes are in all the routers' routing tables.
Metric	The numeric value that describes how good a particular route is. The lower the value is, the better the route is.

Foundation Summary

The "Foundation Summary" section of each chapter lists the most important facts from the chapter. Although this section does not list every fact from the chapter that will be on your CCNA exam, a well-prepared CCNA candidate should know, at a minimum, all the details in each "Foundation Summary" section before going to take the exam.

All routing protocols have several general goals, as summarized in the following list:

- To dynamically learn and fill the routing table with a route to all subnets in the network.
- If more than one route to a subnet is available, to place the best route in the routing table.
- To notice when routes in the table are no longer valid, and to remove those routes from the routing table.
- If a route is removed from the routing table and another route through another neighboring router is available, to add the route to the routing table. (Many people view this goal and the preceding one as a single goal.)
- To add new routes, or to replace lost routes with the best currently available route, as quickly as possible. The time between losing the route and finding a working replacement route is called *convergence time*.
- To prevent routing loops.

The following list summarizes a few very important terms related to routing and routing protocols:

- A *routing protocol* fills the routing table with routing information. Examples include RIP and IGRP.
- A *routed protocol* is a protocol with OSI Layer 3 characteristics that define logical addressing and routing. The packets defined by the network layer (Layer 3) portion of these protocols can be routed. Examples of protocols include IP and IPX.
- The term *routing type* has been used in other Cisco courses, so you also should know this term. It refers to the type of routing protocol, such as link-state or distance vector.

Table 14-8 lists some of the major comparison points between interior routing protocols.

Table 14-8 *Major Comparison Points Between Interior Routing Protocols*

Point of Comparison	Description
Type of routing protocol	Each interior routing protocol covered in this chapter can be characterized based on the underlying logic used by the routing protocol. This underlying logic often is referred to as the type of routing protocol. The three types are distance vector, link state, and hybrid.
Full/partial updates	Some interior routing protocols send their entire routing tables regularly, which is called *full routing updates*. Other routing protocols send only a subset of the routing table in updates, typically just the information about any changed routes. This is called *partial routing updates*. Partial updates require less overhead in the network.
Convergence	Convergence refers to the time required for routers to react to changes (for example, link failures and router failures) in the network, removing bad routes and adding new, better routes so that the current best routes are in all the routers' routing tables.
Metric	The numeric value that describes how good a particular route is. The lower the value is, the better the route is. Some metrics provide a more realistic perspective on which routes are truly the best routes.
Support for VLSM	*Variable-length subnet masking (VLSM)* means that, in a single Class A, B, or C network, multiple subnet masks can be used. The advantage of VLSM is that it enables you to vary the size of each subnet, based on the needs of that subnet. For instance, a point-to-point serial link needs only two IP addresses, so a subnet mask of 255.255.255.252, which allows only two valid IP addresses, meets the requirements but does not waste IP addresses. A mask allowing a much larger number of IP addresses then can be used on each LAN-based subnet. Some routing protocols support VLSM, and some do not.
Classless or classful	*Classless routing protocols* transmit the subnet mask along with each route in the routing updates sent by that protocol. *Classful routing protocols* do not transmit mask information. So, only classful routing protocols support VLSM. To say that a routing protocol is classless is to say that it does support VLSM, and vice versa.

Table 14-9 summarizes the most important points of comparison between the interior routing protocols.

Table 14-9 *Interior IP Routing Protocols Compared—Summary*

Routing Protocol	Metric	Convergence Speed	Supports VLSM, and Is a Classless Routing Protocol	Period for Full routing Updates
RIP-1	Hop count	Slow	No	30 seconds
RIP-2	Hop count	Slow	Yes	30 seconds
IGRP	Calculated based on constraining bandwidth and cumulative delay	Slow	No	90 seconds
EIGRP	Same as IGRP, except multiplied by 256	Very fast	Yes	N/A
OSPF	Cost, as derived from bandwidth by default	Fast	Yes	N/A
Integrated IS-IS	Metric	Fast	Yes	N/A

Table 14-10 outlines some of the key comparison points between RIP and IGRP.

Table 14-10 *RIP and IGRP Feature Comparison*

Feature	RIP (Default)	IGRP (Default)
Update timer	30 seconds	90 seconds
Metric	Hop count	Function of bandwidth and delay (the default). Can include reliability, load, and MTU.
Hold-down timer	180	280
Flash (triggered) updates	Yes	Yes
Mask sent in update	No	No
Infinite-metric value	16	4,294,967,295

Q&A

As mentioned in the introduction, you have two choices for review questions. The questions that follow give you a bigger challenge than the exam itself by using an open-ended question format. By reviewing now with this more difficult question format, you can exercise your memory better and prove your conceptual and factual knowledge of this chapter. The answers to these questions are found in Appendix A.

For more practice with exam like question formats, including questions using a router simulator and multiple-choice questions, use the exam engine on the CD.

1. Which interior IP routing protocols covered in this chapter support VLSM?
2. Which IP routing protocols covered in this chapter use distance vector logic?
3. Which interior IP routing protocols covered in this chapter are considered to converge quickly?
4. Compare distance vector and link-state protocols in terms of what information is sent in routing updates.
5. List three similarities between EIGRP's balanced hybrid logic and link-state logic.
6. Explain the basic concept behind why some routing protocols support VLSM and some do not.
7. Explain the difference between interior and exterior routing protocols.
8. Explain the difference between full and partial routing updates.
9. Define the term balanced hybrid in relation to the terms distance vector and link state.
10. Compare and contrast the types of information sent in distance vector routing updates versus link-state routing updates.
11. What term describes the underlying logic behind the OSPF routing protocol?

Cisco Published INTRO Exam Topics* Covered in This Part:

9 Describe and install the hardware and software required to be able to communicate via a network

13 Define and describe the structure and technologies of computer networks

14 Describe the hardware and software required to be able to communicate via a network

17 Identify the key characteristics of common wide area networking (WAN) configurations and technologies, and differentiate between these and common LAN technologies

19 Describe the role of a router in a WAN

* Always re-check www.cisco.com for the latest posted exam topics

PART V: Wide-Area Networking

Chapter 15: Remote Access Technologies

This chapter covers the following subjects:

- Perspectives on the PSTN
- Analog Modems
- Integrated Services Digital Network
- Digital Subscriber Line
- Cable Modems
- Comparison of Remote Access Technologies

CHAPTER 15

Remote Access Technologies

Earlier in this book, you learned about Ethernet LANs, point-to-point WAN links, and Frame Relay. All of these technologies can be used to connect a corporate site to the Internet. However, none of these options is cost-effective for connecting the typical home-based user to the Internet.

In this chapter, you will learn about several different technologies used for Internet access from the home. Some of these same technologies can be used to remotely access corporate networks as well. This chapter covers the most common remote access technologies—namely, analog modems, DSL, ISDN, and cable.

AUTHOR'S NOTE While they may be on the CCNA exam, the topics in this chapter are less likely to be on the CCNA exam than most other topics in this book. For those of you that are planning to take the CCNA exam, instead of taking both the INTRO and ICND exams, you might consider skipping this chapter. Refer to the introduction to this book for more perspectives on the CCNA exam topics.

"Do I Know This Already?" Quiz

The purpose of the "Do I Know This Already?" quiz is to help you decide whether you really need to read the entire chapter. If you already intend to read the entire chapter, you do not necessarily need to answer these questions now.

The 15-question quiz, derived from the major sections in the "Foundation Topics" portion of the chapter, helps you determine how to spend your limited study time.

Table 15-1 outlines the major topics discussed in this chapter and the "Do I Know This Already?" quiz questions that correspond to those topics.

Table 15-1 *"Do I Know This Already?" Foundation Topics Section-to-Question Mapping*

Foundations Topics Section	Questions Covered in This Section
Perspectives on the PSTN	1—2
Analog Modems	3—4
ISDN	5—7
DSL	8—10
Cable Modems	11—12
Comparisons of Remote Access Technologies	13—15

CAUTION The goal of self-assessment is to gauge your mastery of the topics in this chapter. If you do not know the answer to a question or are only partially sure of the answer, you should mark this question wrong for purposes of the self-assessment. Giving yourself credit for an answer that you correctly guess skews your self-assessment results and might provide you with a false sense of security.

1. Which of the following acronyms identifies a voice codec used to encode analog voice signals into a 64-kbps digital data stream?

   a. PSTN
   b. MCNS
   c. ADSL
   d. PCM
   e. AS-CELP

2. How many DS0 channels are in a DS1 in the United States?

   a. 1
   b. 2
   c. 8
   d. 16
   e. 24
   f. 28
   g. 32

3. Which of the following best describes the function of demodulation by a modem?
   a. Encoding an incoming analog signal as a digital signal
   b. Decoding an incoming digital signal into an analog signal
   c. Encoding a set of binary digits as an analog electrical signal
   d. Decoding an incoming analog electrical signal into a set of binary digits
   e. Encoding a set of binary digits as a digital electrical signal
   f. Decoding an incoming digital electrical signal into a set of binary digits

4. Which of the following modem standards do not support 56-kbps speeds downstream?
   a. V.22
   b. V.22bis
   c. V.42
   d. V.90
   e. V.92
   f. V.32
   g. V.32bis
   h. V.34

5. Which of the following terms best describes features of an ISDN PRI in Europe?
   a. B+D
   b. 2B+D
   c. 23B+D
   d. 24B+D
   e. 30B+D
   f. 31B+D
   g. 32B+D

6. Imagine that you plug an analog phone into an ISDN modem and call a friend at her house, where she uses an analog phone using plain-old telephone service (POTS). At which of the following points in a network will a voice codec be used?
   a. Your friend's telephone
   b. The phone switch into which your friend's local line is connected
   c. The phone switch into which your ISDN BRI line is connected
   d. Your ISDN modem
   e. Your telephone

7. What does the letter B stand for in the ISDN term *B channel*?
   a. Bearer
   b. Broadband
   c. Binary
   d. Best

8. Which of the following DSL standards has a limit of 18,000 feet for the length of the local loop?
   a. IDSL
   b. DSL
   c. ADSL
   d. VDSL
   e. HDSL

9. Imagine a local phone line from a house to a local telco CO. When the customer at that house requests DSL service, what type of device does the telco move the CO end of the local line to?
   a. DSLAM
   b. DSL router
   c. DSL modem
   d. Class 5 switch
   e. Voice switch
   f. Head end

10. Which of the following protocols are used by DSL modem and routers for data link layer functions?

    a. PPP
    b. IEEE 802.3
    c. ATM
    d. IEEE 802.1Q
    e. MCNS MAC

11. Which of the following protocols is used by cable modems for data link layer functions?

    a. PPP
    b. IEEE 802.3
    c. ATM
    d. IEEE 802.1Q
    e. MCNS MAC

12. Which of the following protocols are used by a cable modem for the upstream data?

    a. PCM
    b. QAM-16
    c. QAM-64
    d. QAM-256
    e. QPSK

13. Which of the following remote access technologies uses ATM, Ethernet, and PPP as data-link protocols?

    a. Analog modems
    b. ISDN
    c. DSL
    d. Cable modems

14. Which of the following remote access technologies support specifications that allow both symmetric speeds and asymmetric speeds?

    a. Analog modems
    b. ISDN
    c. DSL
    d. Cable modems

15. Which of the following remote access technologies, when used to connect to an ISP, is considered to be an "always on" service?

    a. Analog modems
    b. ISDN
    c. DSL
    d. Cable modems

The answers to the "Do I Know This Already?" quiz are found in Appendix A, "Answers to the 'Do I Know This Already?' Quizzes and Q&A Sections." The suggested choices for your next step are as follows:

- **12 or less overall score**—Read the entire chapter. This includes the "Foundation Topics" and "Foundation Summary" sections and the Q&A section.
- **13-15 overall score**—If you want more review on these topics, skip to the "Foundation Summary" section and then go to the Q&A section. Otherwise, move to the next chapter.

Foundation Topics

Many companies like the idea of letting workers telecommute, working out of their houses. To gain access to applications residing at the corporate site, companies can support various types of dynamic access to the corporate network for the home user. For instance, a home-based worker might use a modem to dial into the corporate site.

At the same time, most corporations today connect to the Internet using a leased WAN connection of some kind, typically one or more T1 circuits, or possibly even T3 circuits. If their home-based users have access to the Internet, the users could be allowed to access the necessary corporate applications and data through their Internet connection. Depending on the geography, fees for Internet access, and other factors, allowing access through the Internet might be cheaper than providing the capability for users to connect directly into the corporate network.

This chapter begins by covering some background information about the Public Switched Telephone Network (PSTN). Most remote access technologies use the PSTN for basic physical access. The chapter continues with coverage of each of the four types of remote access technologies—modems, ISDN, DSL, and cable.

Perspectives on the PSTN

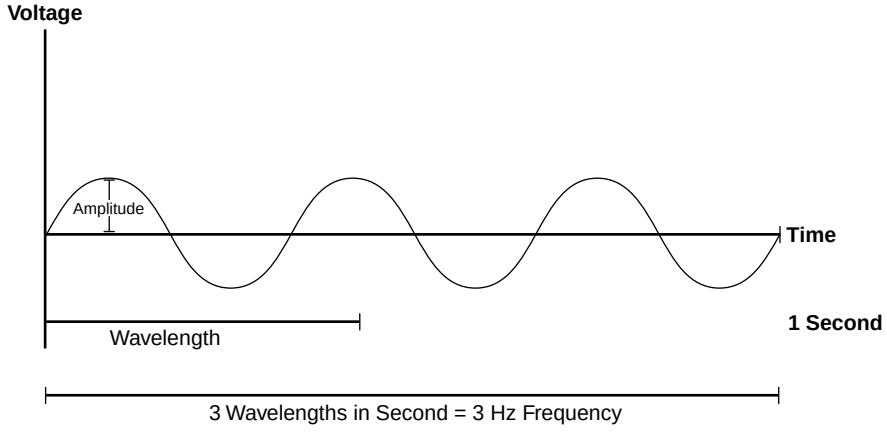
The Public Switched Telephone Network (PSTN) was built to support traffic between telephones—in other words, voice traffic. Three of the four access technologies covered in this chapter happen to use the PSTN, so a basic understanding of the PSTN can help you appreciate how modems, ISDN, and DSL work. If you already know a fair amount about the PSTN, feel free to jump ahead to the section titled "Analog Modems."

Sound waves travel through the air by vibrating the air. The human ear hears the sound because the ear vibrates as a result of the air inside the ear moving, which, in turn, causes the brain to process the sounds that were heard by the ear.

The PSTN, however, cannot forward sound waves. Instead, a telephone includes a microphone, which simply converts the sound waves into an analog electrical signal. The PSTN can send the electrical signal between one phone and another. On the receiving side, the phone converts the electrical signal back to sound waves using a speaker that is inside the part of the phone that you put next to your ear.

The analog electrical signals used to represent sound can be shown on a graph, as in Figure 15-1.

Figure 15-1 *Analog Electrical Signal: Frequency, Amplitude, and Phase*



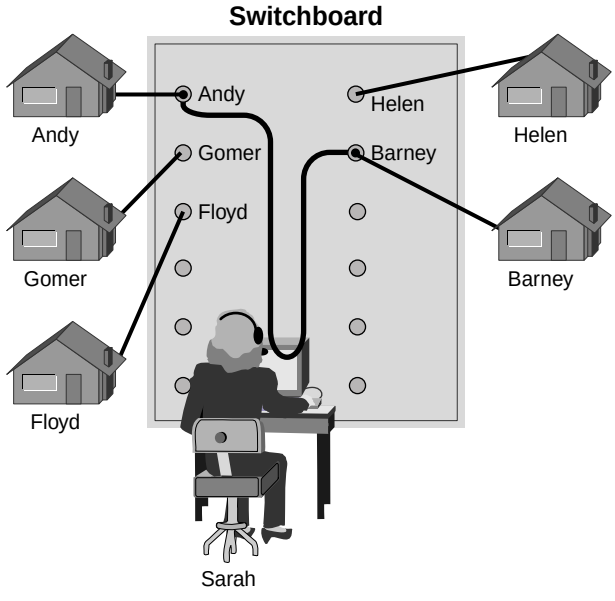
The graph represents the three main components of the signal:

- **Frequency**—Frequency is defined as how many times the signal would repeat itself, from peak to peak, in 1 second (assuming that the sound didn't change for a whole second.) The figure shows a frequency of 3 Hertz (Hz). The greater the frequency of the electrical signal is, the higher the pitch is of the sound being represented.
- **Amplitude**—The amplitude represents how strong the signal is; a higher amplitude peak represents a louder sound.
- **Phase**—Phase refers to where the signal is at a point in time—at the top, going down, at the bottom, going up, and so on.

The goal of the original PSTN was to create a circuit between any two phones. Each circuit consisted of an electrical path between two phones, which, in turn, supported the sending of an analog electrical signal in each direction, allowing the people on the circuit to have a conversation. Remember, the original PSTN, built by Alexander Graham Bell's new company, predated the first vacuum tube computers, so the concept of support data communication between computers wasn't a consideration for the original PSTN. It just wanted to get these analog electrical signals, which represented sounds, from one place to the other.

To set up a circuit, when the PSTN first got started, you picked up your phone. A flashing light at a switchboard at the local phone company office told the operator to pick up the phone, and then you told the operator who you wanted to talk to. If it was a local call, the operator completed the circuit literally by patching the cable at the end of the phone line connected to your house to the end of the phone line connected to the house of the person you were calling. Figure 15-2 depicts the basic concept.

Figure 15-2 *Human Operator Setting Up a Circuit at a Switchboard*



In the figure, Sarah, the operator, picks up the phone when she sees a light flashing telling her that someone at Andy's house has picked up the phone. Andy might say something like, "Sarah, I want to talk to Barney." Because Andy, Sarah, and Barney probably all knew each other, that was enough. In a larger town, Andy might simply say, "Please ring phone number 555-1212," and Sarah would connect the call. In fact, patching the call on the switchboard is where we got the old American saying "patch me through."

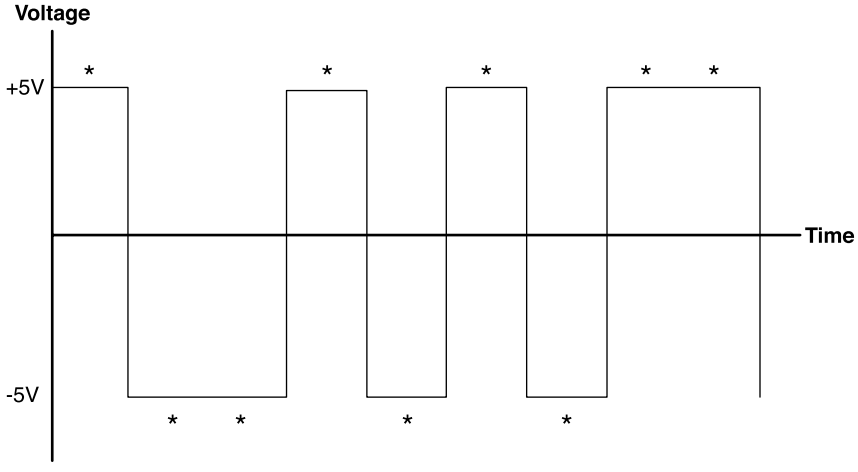
Over the years, the signaling to set up a circuit got more sophisticated. Phones evolved to have a rotary dial on them, so you could just pick up the phone and dial the number you wanted to call. Later, 12-digit keypads replaced the dial so that you could simply press the numbers. For those of you who do not remember phones with dials on them, it would have taken you 20 seconds to dial a number that had lots of 8s, 9s, and 0s in them, so a keypad was a big timesaver!

The PSTN also evolved to use digital signals instead of analog signals inside the core of the PSTN. By using digital signals instead of analog, the PSTN could send more voice calls over the same physical cables, which, in turn, allowed it to grow while reducing the per-call-minute cost.

So, what is a digital signal? Digital signals represent binary numbers. Electrically, digital signals use a defined set of both positive and negative voltages, which, in turn, represent

either a binary 0 or a binary 1. *Encoding schemes* define the rules as to which electrical signals mean a binary 0 and which ones mean a binary 1. The simplest encoding scheme might be to represent a binary 1 with +5V and a binary 0 with —5V; much more sophisticated encoding schemes are used today. Figure 15-3 shows an example of a graph of a digital signal over time, using the basic encoding scheme that was just described.

Figure 15-3 *Example of a Digital Signal with a Simple Encoding Scheme*



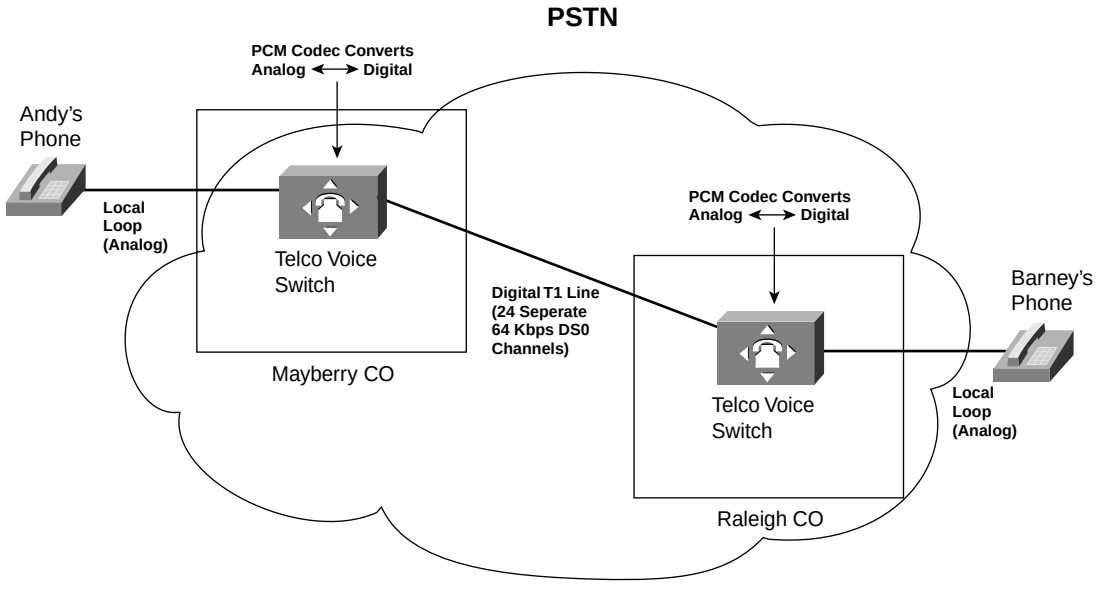
The sender of the digital signal simply varies the signal based on the encoding scheme. The receiver interprets the incoming signal according to the same encoding scheme, re-creating the digits. In the figure, if the receiver examined the signal at each point with an asterisk, the binary code would be 100101011.

So, if a device wanted to somehow send a set of binary digits to another device and there was a digital circuit between the two, it could send the appropriate digital signals over the circuit. To achieve a particular bit rate, the sender would make sure that the voltage level was at the right level at regular intervals, and the receiver would sample the incoming signal at the same rate. For instance, to achieve 28 kbps, the sender would change (as necessary) the voltage level every 1/28,000th of a second. The receiver would sample the incoming digital signal every 1/28,000th of a second as well.

Converting Analog Voice to Digital Voice

The last step in understanding how the PSTN supports voice across a digital PSTN relates to how the PSTN converts the analog electrical signals to digital signals, and vice versa. To see the need for the conversion, examine Figure 15-4.

Figure 15-4 *Analog Voice Calls Through a Digital PSTN*



When Andy calls Barney in Raleigh, the circuit is set up by the telco. (Yes, Barney moved to Raleigh since the last example.) And it works! It works because the phone company switch in the Central Office (CO) in Mayberry performs analog-to-digital (A/D) conversion of Andy's incoming voice. When the switch in Raleigh gets the digital signal, before sending it out the analog line to Barney's house, it reverses the process, converting the digital signal back to analog. The analog signal going over the local line to Barney's house is roughly the same analog signal that Andy's phone sent over his local line.

The original standard for converting analog voice to a digital signal is called *pulse-code modulation* (*PCM*). PCM defines that an incoming analog voice signal should be sampled 8000 times per second by the analog-to-digital (A/D) converter. A/D converters that are used specifically for processing voice are called *codecs* (meaning encoder/decoder). For each sample, the codec measures the frequency, amplitude, and phase of the analog signal. PCM defines a table of possible values for frequency/amplitude/phase. The codec finds the table entry that most closely matches the measured values. Along with each entry is an 8-bit binary code, which tells the codec what bits to use to represent that single sample. So PCM, sampling at 8000 times per second finds the best match of frequency/amplitude/phase in the table, finds the matching 8-bit code, and sends those 8 bits as a digital signal.

The PCM codec converts from digital to analog by reversing the process. The decoding process re-creates the analog signal, but not quite exactly. For instance, if the original

frequency was 2139.3, the decoded frequency might be 2140. For normal speech, the quality is great. If you were trying to listen to DVD-quality sounds over the telephone, it probably wouldn't sound as good as it would if you were actually there, but it's pretty close.

If you do the math, you will notice that a single voice call requires 64 kbps of bandwidth in the digital part of the PSTN. PCM says that you need to sample the analog signal 8000 times per second, and each sample needs 8 bits to represent it. A bright fellow at Bell Labs, Nyquist, did some research that showed this sampling rate was needed for digitized voice. He noticed that the human voice could create sounds between 300 Hz and 3300 Hz, and that the sampling rate needed to be twice that of the highest frequency. So, to overcome some other physics problems, Nyquist and the team at Bell Labs decided to round that range of frequencies for the human voice to 0 Hz to 4000 Hz. So, because Nyquist's theorem states that you need twice the number of samples as the highest frequency, you need 8000 samples. To make sure the voice sounded good after being decoded, they decided to use 256 different binary values, each representing a different combination of amplitude, frequency, and phase. To represent the 256 values, they needed 8 bits; for 8000 samples per second, 64 kbps is needed for a PCM-encoded voice call.

Because a single call needs 64 kbps, the digital PSTN first was built on a basic transmission speed of 64 kbps. A single 64-kbps channel was dubbed a Digital Signal Level 0—or DS0. In the United States, the phone company (American Telephone and Telegraph [AT&T] by that point in its history) decided to create hardware that could multiplex 24 DS0s onto a single line, so it called that type of line a Digital Signal Level 1—or DS1. The more popular name for a DS1 today, of course, is T1. Some parts of the world followed AT&T's lead for DS1 with 24 DS0 channels, and other parts of the world, mainly Europe and Australia, chose instead to combine 32 different 64-kbps DS0 channels onto a single line, which is the basis for today's E1s. As you might imagine, even faster digital facilities are defined as well, such as a T3-line, which has 28 T1s in it.

Finally, this small history lesson comes to an end. Most of the work on modems and ISDN, and some of the work for DSL, occurred with the expectation that these technologies needed to work over the PSTN.

In summary:

- The telco switch in the CO expects to send and receive analog voice over the physical line to a typical home (the *local loop*).
- The telco converts the received analog voice to the digital equivalent using a codec.
- The telco converts the digital voice back to the analog equivalent for transmission over the local loop at the destination.
- The voice call, with PCM in use, uses 64 kbps through the digital part of the PSTN.

Analog Modems

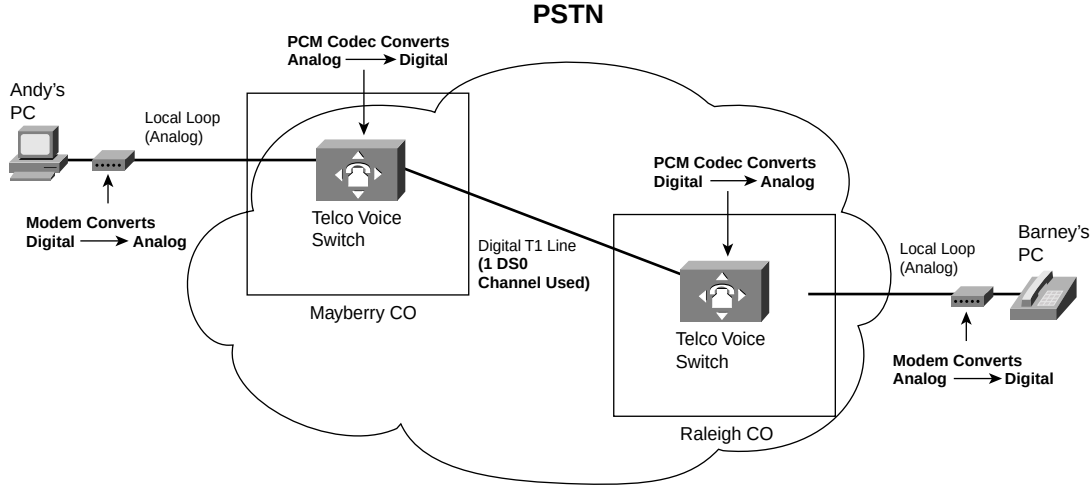
Analog modems allow two computers to send and receive a serial stream of bits, with no physical changes required on the typical analog local loop between a residence and the telco CO. Because the switch in the CO expects to send and receive analog voice signals over the local loop, modems simply send an analog signal to the PSTN and expect to receive an analog signal from the PSTN. However, that analog signal represents some bits that the computer needs to send to another computer, instead of voice created by a human speaker. Similar in concept to a phone converting sound waves into an analog electrical signal, a modem converts a string of binary digits on a computer into a representative analog electrical signal.

Modems encode a binary 0 or 1 onto the analog signal by varying the frequency, amplitude, or phase. Changing the analog signal is referred to as modulation. For instance, one of the earliest standards called for a modem to send an analog signal of 2250 Hz for a binary 1, and 2100 Hz for binary 0. A modem would modulate, or change, between the two frequency levels to imply a binary 1 or 0.

To achieve a particular bit rate, the sending modem would modulate the signal at that rate. For instance, to send 9600 bps, the sending modem would change the signal (as necessary) every 1/9600th of a second. Similarly, the receiving modem would sample the incoming analog signal every 1/9600th of a second, interpreting the signal as a binary 1 or 0. (The process of the receiving end is called *demodulation*. The term *modem* is a shortened version of the combination of the two words *modulation* and *demodulation*.)

Modems must work over the existing PSTN. Figure 15-5 outlines the basic process.

Figure 15-5 *Basic Operation of Modems over PSTN*



First, a circuit (call) must be established. One modem signals the phone number for the call in the same way that a telephone does today, by sending the tones associated with the keys on a telephone keypad. The CO switch interprets these tones, called dual-tone multifrequency (DTMF) tones, just like it would for a voice call.

When the circuit has been established by the telco, the two modems must agree to what modem standard they will use. As long as the two modems use the same rules for how they perform modulation and demodulation, the modems can communicate. Many modem standards exist, and many modems support several standards. Modems can probe and negotiate to find the best modem standard that both endpoint modems support. These standards are explained briefly and listed later in the chapter.

Note that the PSTN still converts the analog signals to and from PCM using a codec. In effect, the data ping-pongs between different states as it passes through the network:

1. The bits start out stored in digital form on a computer.
2. The bits are converted to an analog signal by the modem.
3. The analog signal is converted into a different digital format by a switch in the PSTN, using a PCM codec.
4. The CO switch near the receiving end using a PCM codec to convert back to an analog signal.
5. The receiving modem converts the incoming analog signal to the correct set of bits.

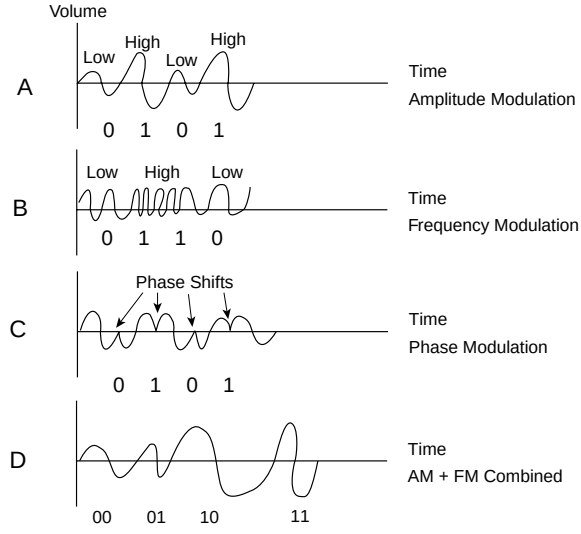
Modems work well and have been around for a long time, so the conversion steps do not pose a problem.

Modulation and Demodulation

Most people can fully appreciate the concept of the speed of a dialed circuit in terms of bits per second. However, another term, baud, often is used to describe the speed of a modem. In fact, some people say things like “That modem runs at 33 kilo baud per second,” really meaning 33 kilobits per second (kbps), thinking that “bits per second” and “baud per second” are the same thing. But the two terms are not synonymous, as you will read shortly.

Modems create an analog signal when sending data. As mentioned earlier, analog electrical signals can be analyzed in terms of frequency, amplitude, and phase. So, modem standards define that particular values for these three parts of the signal imply a 1 or a 0. To appreciate what that means, consider the two parts of Figure 15-6.

Figure 15-6 *Amplitude, Frequency, and Phase Modulation*



The figure depicts some very simple ways that a modem could be used to create an analog signal that can be interpreted by the receiver as a set of binary digits. In Graph A, a low amplitude means a binary 0, and a high amplitude means a binary 1. All the sending modem has to do is modulate (change) the amplitude of the signal to imply a 1 or a 0. For instance, if the modem was running at 28 kbps, then every 1/28,000th of a second, it would make the amplitude of the signal low or high, to encode a binary 0 or 1.

The process of changing, or modulating, the amplitude is called *amplitude modulation*. Modulation, as defined by www.dictionary.com, is "the variation of a property of an electromagnetic wave or signal, such as its amplitude, frequency, or phase," which is exactly what amplitude modulation does, specifically for the amplitude.

Graph B in Figure 15-6 depicts *frequency modulation*. In this simple example, the higher frequency (the part with the curved lines closer together) means 0, and the lower frequency means 1. Notice that the amplitude stays the same in that case, so this modem standard simply changes the frequency to imply a 1 or a 0. So, if the modems are running at 28 kbps, then every 1/28,000th of a second, the modem would make the frequency high or low to encode a binary 0 or 1.

Graph C in Figure 15-6 depicts *phase modulation*. Phase modulation changes the phase of the signal—instead of the signal following its normal pattern of rising to the highest positive voltage, gradually lowering to the lowest voltage and back again, the signal changes directions—which changes the phase. Modems can modulate the phase to imply a binary 0 or 1 as well.

Finally, Graph D in Figure 15-6 shows a combination of frequency modulation and amplitude modulation. With this final scheme, each signal represents 2 bits. For instance, a

low-amplitude and low-frequency signal might mean 00, whereas a low-amplitude but high-frequency signal might mean 01. Table 15-2 lists the four combinations possible with this example combined modulation scheme.

Table 15-2 *Combinations of Bits with FM and AM Together*

Amplitude	Frequency	Used for This Binary Code
Low	Low	00
Low	High	01
High	Low	10
High	High	11

The modulation scheme in Graph D of Figure 15-6 provides a good context from which to understand the term *baud*. To achieve higher bit rates, modems tend to use modulation techniques that encode more than 1 bit in the signal, as in this example. For instance, to achieve 28 kbps with this last modulation scheme, the modems would need to change (sender) or sample (receiver) the analog signal only every 1/14,000th of a second, because each sample represents 2 bits.

The term *baud* refers to a single encoded energy signal that can represent 1 or more bits. In this final example, a baud happens to represent 2 bits. Baud is not an acronym; it is taken from the name of the inventor (Baudot) of one of the first modulation schemes that implied more than 1 bit. So, the modem running at 28,000 bps, with a modulation scheme that sends/receives 2 bits per baud, is running at 14,000 baud per second.

Point-to-Point Protocol Features with Modems

Most computers today use PPP as the data-link protocol when using modems. Modems essentially provide an OSI Layer 1 service, supporting the transmission and reception of a serial bit stream. In fact, a dialed circuit between two modems creates a physical network that has a lot of similarities with a leased point-to-point circuit. Also, analog modems typically transmit traffic asynchronously. PPP supports both synchronous communication, as typically is done over leased point-to-point lines, as well as asynchronous communication, which typically is done over dialed circuits using modems. So, PPP is the logical choice for a data-link protocol when using modems today.

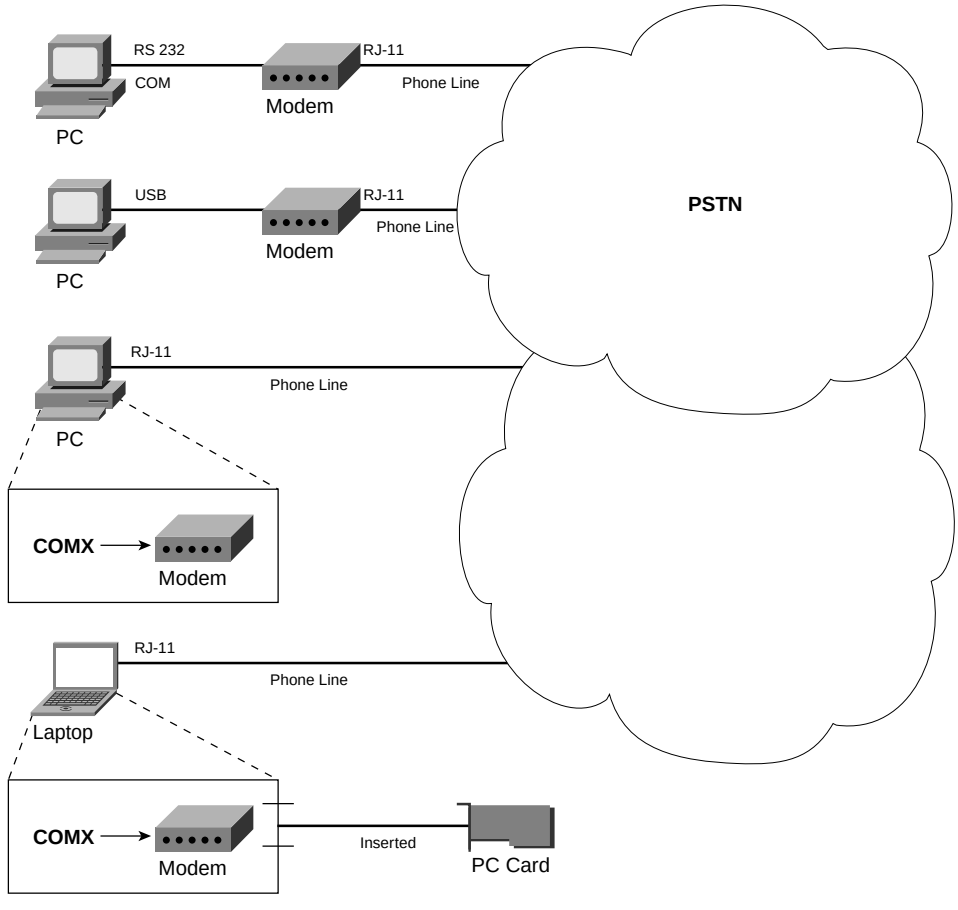
PPP includes some features that are important when using modems to dial into an ISP. PPP includes the capability of dynamically assigning an IP address to a device on the other end of the PPP link. So, when you dial into an ISP, the ISP dynamically assigns an IP address to your computer. Also, PPP supports that Challenge Handshake Authentication Protocol (CHAP), which popularly is used to allow the dial-in user to supply a username and password to gain access to the ISP network. (CHAP is covered in the *CCNA ICND Exam Certification Guide*.)

Modem Installation and Cabling

PC modems can be located internally or externally. Internal modems are placed inside the PC itself, whereas external modems are external to the PC. Laptops might come with a modem built in or simply might use a convenient type of internal modem called a PCMCIA card, or simply PC card. PC cards are roughly the size of a credit card and easily can be inserted and removed from a PC.

Most PC hardware comes with either a serial communications port, called a COM port, or a Universal Serial Bus (USB) port. Both USB and COM ports are intended to support external devices that communicate using a serial bit stream. So, External modems can be connected to a PC using either a COM port or a USB port. Figure 15-7 depicts the typical topology.

Figure 15-7 *Modem Installation Options and Concepts*



COM ports usually consist of either a female RS-232 connector, which is a D-shell connector with 25 pins, or a DB-9 connector, which uses 9 pins. USB ports are rectangular female

connectors about one quarter inch by 1 inch long. In either case, the computer sends a serial bit stream to the external modem over the cable, expecting the modem to send the data. At the same time, the modem forwards bits received from the phone line back to the PC.

Internal modems do not require the use of an RS-232, DB-9, or USB cable—they simply connect directly to the phone line. In the United States, that means using the same type of cable that is used to connect to an analog phone, with an RJ-11 connector. However, the installation of an internal modem still uses the logical concept of a COM port. That is true of internal modems that are installed in an expansion card slot and of PCMCIA modems that simply can be inserted into the convenient PC card slot in the side of a laptop computer. The operating system in the computer still uses the concept of sending data serially, but instead of it physically being sent over a cable to an external modem, it simply goes to the internal modem card.

Modem Standards

Modems have been around for more than 30 years, so as you might imagine, a lot of standards have evolved. Table 15-3 summarizes some of the modem standards.

Table 15-3 *Modem Standards*

Standard	Speed	Comments
V.22	1200 bps (600 baud)	Mainly used outside the United States
V.22bis*	2400 bps (600 baud)	First widely deployed worldwide standard
V.32	4800/9600 (2400 baud)	Adjusts speed based on line quality
V.32bis*	14.4kbps (2400 baud)	Backward compatible with V.32
V.34	28.8 kbps	Backward compatible with V.32bis and V.32
V.42	28.8 kbps	Same speed as V.34, but with error-correction features
V.90	56 kbps (downstream), 33 kbps (upstream)	Created from two earlier competing standards, X2 and K56Flex
V.92	56 kbps/33 kbps (downstream/upstream) or 48 kbps (each direction)	Connects and finds correct speed more quickly than V.90; allows "modem-on-hold"

*"bis" simply means "version 2."

Note that for some standards, the speed differs depending on the direction of transmission. Most applications today cause a lot more data to be sent toward the client side of the connection. For instance, when you sit at a PC and browse a web page, the web server sends

many more bytes to you than you send to it. By using modem standards that use asymmetric rates, the maximum rate can be increased for the direction of data that needs the additional bandwidth.

V.92, the latest of these standards, has some very interesting features. You can configure it to transfer data at symmetric (48-kbps) rates or asymmetric rates equivalent to V.90's 56 kbps downstream and 33 kbps upstream. It also allows the modem to recognize "call waiting" signals from the telco, letting you take or make a call while keeping your modem connection up for a short time. Technically, you are not sending data and talking at the same time because data transmission is put "on hold," but it is a very convenient feature.

Analog Modem Summary

Modems have the great advantage of being the most pervasively available remote access technology. The history of modems is long, with modems growing to be a very reliable choice for remote access. Speeds have improved over the years, with compression technology increasing the effective throughput to beyond 100 kbps.

Modems provide a Layer 1 service of delivering a bit stream between the two endpoints on the dialed circuit. To pass IP traffic, an appropriate data-link protocol must be used, typically PPP.

The biggest negatives about using modems include their relatively low speed and the fact that you cannot use the phone at the same time as you send data.

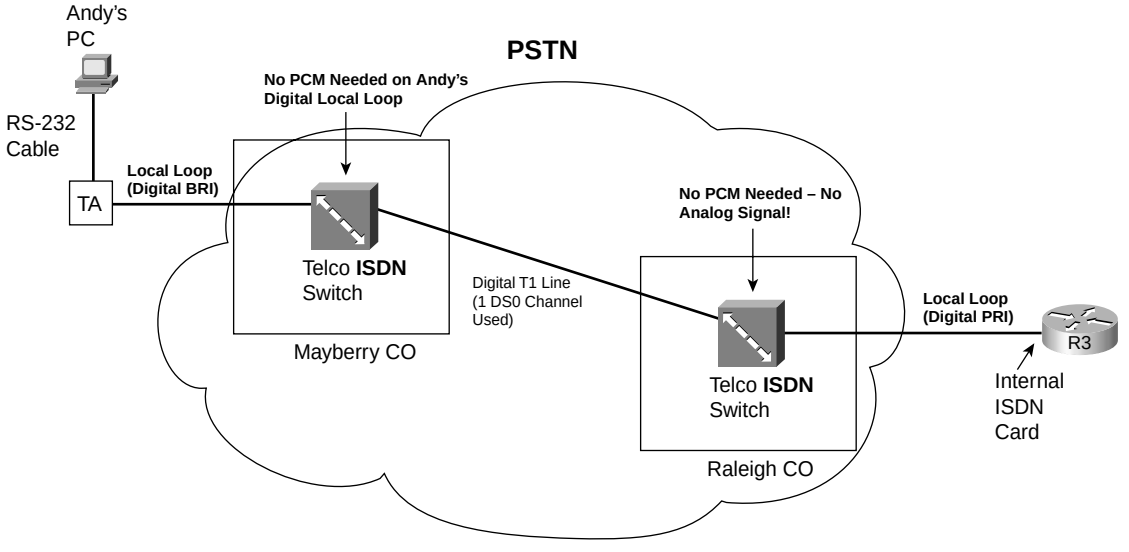
Integrated Services Digital Network

Integrated Services Digital Network (ISDN) provides switched (dialed) digital WAN services in increments of 64 kbps. Before ISDN, the only widely-available method to dial a circuit for data communication between two computers was to use analog modems. When ISDN was created, analog modem speeds typically did not even exceed 9600 bps. The phone companies of the world wanted to have a dialed service that not only allowed faster transmission rates, but also was pervasive as a simple analog line used for voice.

Today one could argue that the collective phone companies of the world were ultimately successful with this goal, but not *totally* successful. ISDN is widely available. It is still a popular technology for dial backup between business sites when a point-to-point or Frame Relay link fails. ISDN was created more than 20 years ago, and it began being widely deployed in the United States by the early 1990s. However, competing technologies, such as DSL and cable, have usurped ISDN in the marketplace for home access to ISPs. However, ISDN remains a popular choice for dial backup.

ISDN requires that the two endpoint computers have the ISDN equivalent of an analog modem. There are many variations of these ISDN devices, mainly as a result of the fact that ISDN was created as a worldwide standard, so many options were needed to meet the differing needs of the telcos in different parts of the world. Figure 15-8 shows the required ISDN hardware for a typical connection.

Figure 15-8 *ISDN Local Loops and Equipment*



Notice that both the home PCs and the router at the ISP use ISDN gear. Routers often use ISDN cards that can be connected directly to the ISDN circuit supplied by the telco. PCs typically use an ISDN device called an ISDN terminal adapter (TA), which often is called an ISDN modem. Because ISDN uses digital signals across the local loop, it does not actually do any modulation or demodulation. However, the term *ISDN modem* emerged because it was cabled and installed similarly to an external analog modem. So, for the consumer marketplace, the marketing people started calling TAs by the technically wrong but easy-to-understand term ISDN modem.

Note that the local loop from the home and the CO now connects to a device called an ISDN switch. Local phone lines typically connect to a voice switch in the CO. ISDN uses digitial signals, so the telco actually must terminate the line from your house in a telco switch that expects digitial signals that conform to ISDN specifications.

ISDN Channels

ISDN includes two types of lines: Basic Rate Interface (BRI) and Primary Rate Interface (PRI). Both BRI and PRI provide multiple digital bearer channels (B channels) over which data can be sent and received. Because both BRI and PRI have multiple B channels, a single BRI or PRI line can have concurrent digital dial circuits to multiple sites. Alternately, you can create multiple circuits to the same remote site to increase available bandwidth to that site.

B channels transport data. They operate at speeds of up to 64 kbps, although the speed might be lower, depending on the service provider, or might be based on standards in some parts of the world. For instance, some national standards outside the United States call for 56-kbps B channels.

ISDN uses another channel inside the same single physical line to ask the telco to set up and tear down circuits. The signaling channel, called the *D channel*, signals new data calls. When a router wants to create a B-channel call to another device using a BRI or PRI, it sends the phone number that it wants to connect to inside a message sent across the D channel. The phone company's switch receives the message and sets up the circuit. Signaling a new call over the D channel is effectively the same thing as when you pick up the phone and dial a number to create a voice call.

The different types of ISDN lines often are descirbed with a phrase that implies the number of each type of channel. For instance, BRIs are referred to as 2B+D, meaning two B channels, and one D channel. PRIs based on T/1 framing, as in the United States, are referred to as 23B+D, and PRIs based on E/1 framing, typically found in Europe, are referred to as 30B+D. E/1s have 32 DS0 channels, with 1 reserved for framing and 1 used for the D channel when used as a PRI—that leaves 30 DS0 channels as B channels. Table 15-4 lists the number of channels for each type of ISDN line and the terminology used to describe them.

Table 15-4 *BRI and PRI B and D Channels*

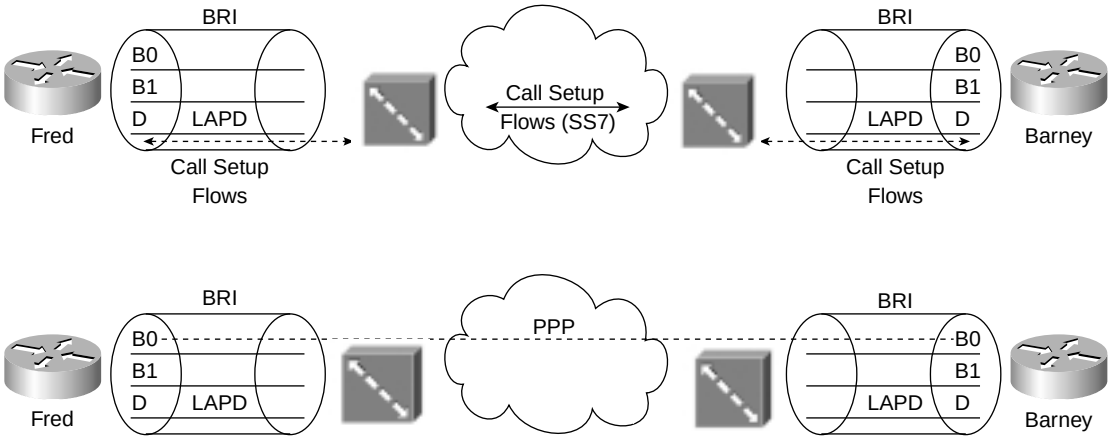
Type of Interface	Number of Bearer Channels (B Channels)	Number of Signaling Channels (D Channels)	Descriptive Term
BRI	2	1 (16 kbps)	2B+D
PRI (T1)	23	1 (64 kbps)	23B+D
PRI (E1)	30	1 (64 kbps)	30B+D

ISDN Call Setup and Data Link Protocols

Call setup differs between ISDN and modems. With a telephone call and with analog modems, DTMF tones are sent across the analog local loop to the telco. The telco switch at the local CO interprets the dialed digits and sets up the call. However, with ISDN, there is no analog local loop over which the analog DTMF tones can be sent.

ISDN devices send and receive signaling messages to and from the local ISDN switch to which it is connected. In telco terminology, *signaling* refers to any type of request to establish a circuit. So, punching keys on your telephone is considered signaling to set up a circuit over an analog local line. Instead of DTMF tones, ISDN defines a set of messages that are sent over the D channel to the local CO. As a result, the PSTN sets up a circuit to the ISDN device whose phone number was put inside the signaling message. Figure 15-9 outlines the process and the result.

Figure 15-9 *D Channel Call Setup Signaling and Resulting B-Channel Call*



The service provider can use anything it wants to set up the call inside its network. ITU Q.931 messages are used for signaling between the ISDN device and the CO; typically, Signaling System 7 (SS7) is used between the two telco switches—the same protocol used inside phone company networks to set up circuits for phone calls.

When the call is established, a 64-kbps circuit exists between a B channel on each of the two routers in the figure. The routers can use High-Level Data Link Control (HDLC), but they typically use PPP as the data-link protocol on the B channel from end to end. As on leased lines and dialed circuits using modems, the switches in the phone company do not interpret the bits sent inside this circuit—they just help create a serial bit stream in each direction.

The D channel remains up all the time so that new signaling messages can be sent and received. Because the signals are sent outside the channel used for data, this is called *out-of-band signaling*.

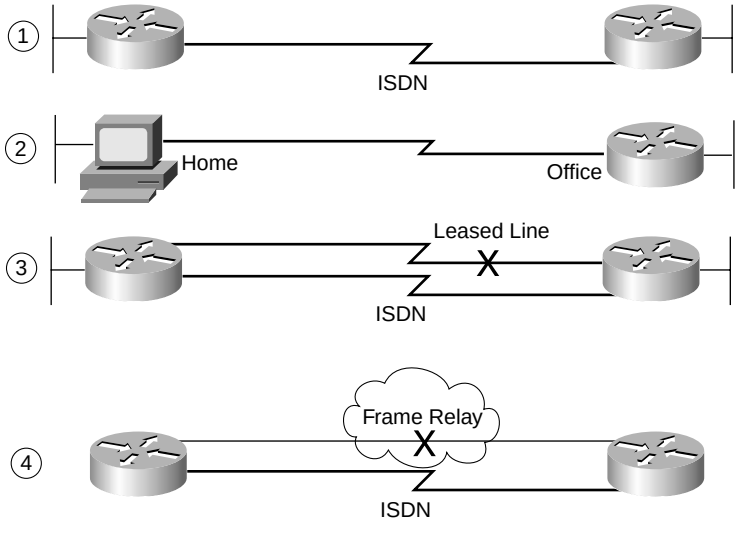
Typical Uses of ISDN

Routers frequently use ISDN to create a backup link when their primary leased line or Frame Relay connection is lost. Although the leased line or Frame Relay access link seldom fails, when it does, a remote site might be completely cut off from the rest of the network. Depending on the business goals of the network, long outages might not be acceptable, so ISDN could be used to dial back to the main site.

The ICND exam covers ISDN as well, including the features and configuration used by routers. The scenarios in Figure 15-10 show some of the typical situations in which ISDN can be used, described as follows:

- Case 1 shows dial-on-demand routing (DDR). Logic is configured in the routers to trigger the dial when the user sends traffic that needs to get to another site.
- Case 2 shows a typical telecommuting environment.
- Case 3 shows a typical dial-backup topology. The leased line fails, so an ISDN call is established between the same two routers.
- Case 4 shows where an ISDN BRI can be used to dial directly to another router to replace a Frame Relay access link or a failed virtual circuit (VC).

Figure 15-10 *Typical Occasional Connections Between Routers*

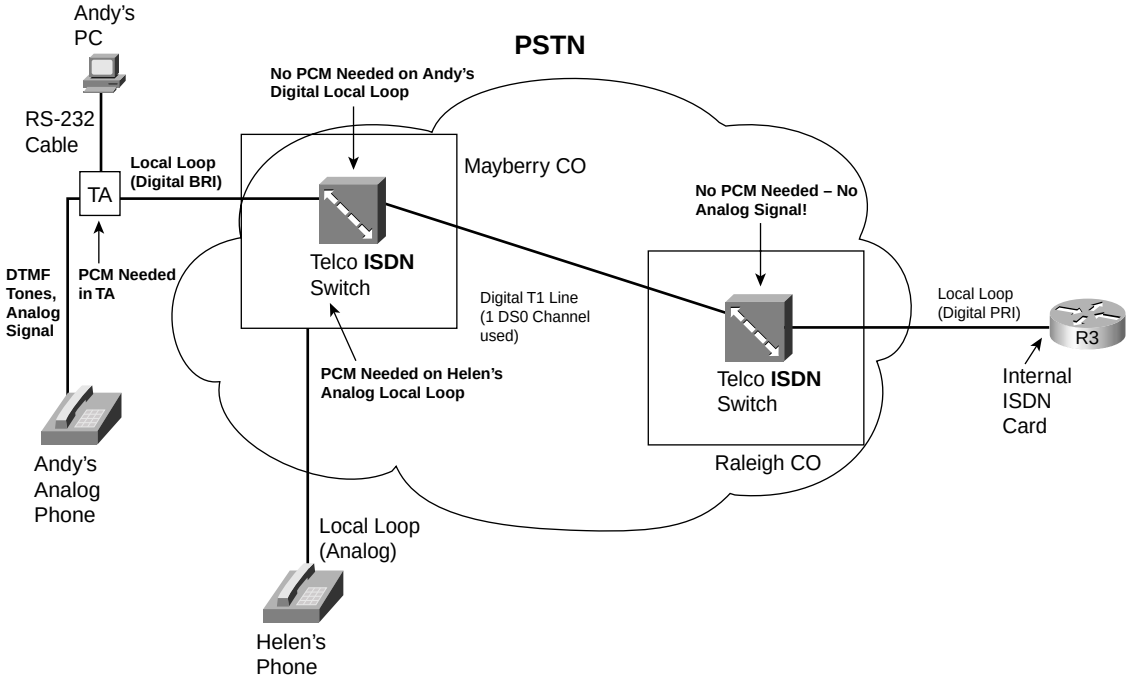


PRIs allow for larger-scale ISDN because they support far more B channels on a single physical line. Imagine an ISP that supports ISDN, with 1000 customers. If that ISP wanted to support up to 230 concurrent ISDN customers, each using a single B channel, that ISP

would need 10 PRIs (assuming that it was in the United States). Also, each user might want to use both B channels at the same time, doubling the speed to the Internet; to support 2 B channels each for 230 concurrent users, that ISP would need 460 B channels, or the equivalent of 20 PRIs. However, if it just used BRI lines, it would need 230 different physical BRI lines, which probably would be much more expensive, would require more equipment, and would be a cabling hassle.

ISDN supports voice as well as data circuits. ISDN BRI circuits do not support analog voice, but they do support digital voice. You might recall that a single PCM voice call requires 64 kbps and that a single B channel provides 64 kbps. So, ISDN devices, like a terminal adapter, perform the PCM encoding and decoding features and send the voice traffic over a B channel. In fact, most ISDN modems have two RJ-11 ports that can be used to connect a normal analog phone. Figure 15-11 depicts the cabling and some important concepts about how it all works.

Figure 15-11 *ISDN Support for Voice*



The analog phone works just like it normally works. You pick it up and punch in some digits, generating DTMF tones. The ISDN TA can't send the tones, so it interprets the tones and generates a signaling message over the D channel. After the telco sets up a circuit over one of the B channels, the TA begins using its PCM codec to convert the incoming analog voice from

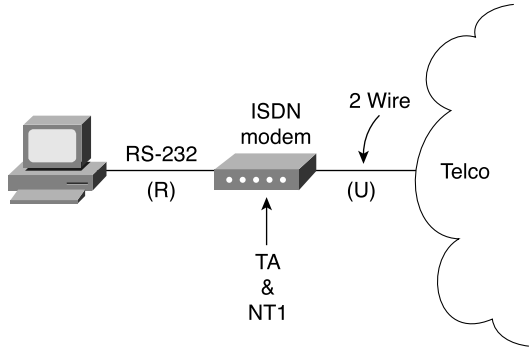
the phone into PCM digits, sending them across the B channel. In the Figure 15-11 example, the other phone is an analog phone connected to the PSTN at Helen's house. So, the voice switch connected to Helen's phone line converts the incoming digital signal from the back to analog voice using a PCM codec, just like it normally does for a call between two analog phone.

Finally, ISDN supports multiple concurrent data bearer channels. For instance, you can use your PC to dial two different sites at the same time. You can make two calls to the same ISP, increasing the speed. You also can use one B channel for data and make a voice call using the other B channel.

ISDN Installation and Cabling

ISDN installation for a home-based PC works much like it does for modems. The most popular option uses an external ISDN modem, or terminal adapter. Figure 15-12 depicts the typical cabling.

Figure 15-12 *Cabling a PC to an ISDN TA*



In this case, a COM port (shown) or a USB port (not shown) connects to the TA. The TA terminates the ISDN cable from the telco.

The cable from the telco uses an RJ-45 connector, the same type used for Ethernet cables. However, the pins used inside the cable are different than those for Ethernet, so do not just grab any old cable with an RJ-45 connector. Piins 3 and 6 are used for transmit and pins 4 and 5 used for receive.

ISDN Summary

ISDN supports a BRI service with 2 B channels, and a PRI service with either 23 (T1) or 30 (E1) B channels. Signaling for call setup and teardown occurs over an out-of-band D channel.

After a circuit has been established over a B channel, ISDN provides a Layer 1 service, delivering a serial bit stream between the two endpoints of the circuit.

ISDN's advantages include the capability to support voice calls concurrently with a data call. Also, ISDN can be used over the local telco loop, with no significant distance limitations. And it provides more bandwidth than do modems, particularly with both B channels dialed to the same remote site.

ISDN does have a few disadvantages, with the biggest disadvantage being the lower speeds than DSL or cable.

Digital Subscriber Line

Any two computers using compatible modems could communicate with each other. Those computers might just be two PCs, a PC dialing into a router or access server at one of the business offices, or a PC dialing into a router or access server at an ISP. As long as both endpoints have a compatible modem, the two can communicate.

By the time DSL came around in the mid- to late 1990s, the main goal for remote access was not the capability to connect to any site anywhere, but to connect to either the Internet or a corporate IP network. In years past, modems were used to dial a large variety of different computers, which was useful. Today you can think of the Internet like you think of the electric company, the gas company, and so on—it's a utility that provides IP connectivity to the rest of the world.

Because most people today just want access to the utility—in other words, the Internet—DSL can be defined a little differently. In fact, DSL was designed to provide high-speed access between a home or business and the local CO. By removing the requirement to allow connection between any two endpoints, DSL can be defined to reach much higher speeds.

Because DSL really just defines how to transmit data between a customer site and the local CO, the expectation with DSL is that the data would not flow through DS0 channels inside the PSTN. Instead, it would be forwarded through some IP network. By removing the need to be compatible with the entirety of the core of the PSTN, DSL can be defined to provide some nice services and better transmission speeds.

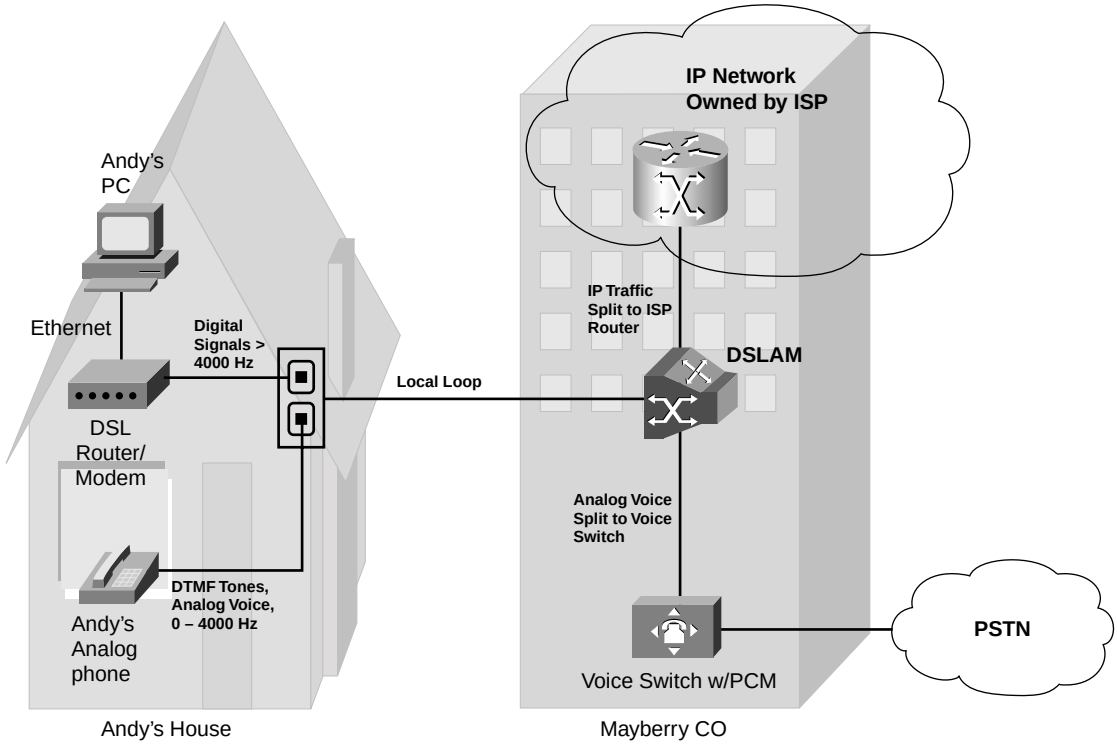
DSL's basic services have some similarities, as well as differences, when compared to analog modems and ISDN lines. Some of the key features are as follows:

- DSL allows analog voice signals and digital data signals to be sent over the same local loop wiring.

- Similar to ISDN, the local loop must be connected to something besides a traditional voice switch at the local CO: a device called a DSL access multiplexer (DSLAM).
- DSL allows for a concurrent voice call to be up at the same time as the data connection.
- Unlike modems and ISDN, DSL's data component is always on—in other words, you don't have to signal to set up a data circuit.

DSL really does provide some great benefits—you can use the same old phones that you already have, you can keep the same phone number, and you can just sit down at your PC at home and start using the Internet. Figure 15-13 shows some of the details of a typical DSL connection.

Figure 15-13 *DSL Connection from the Home*



In the home, a DSL modem or DSL-capable router is connected to the phone line (the local loop) using a typical telephone cable. The cable uses RJ-11 connectors, as is typical for a cable for an analog phone or a modem, with pin 3 for transmit and pin 4 for receive. The DSL modem understands the Layer 1 encoding details for DSL and encodes the data correctly. DSL routers might include the DSL modem feature, as well as providing other

features, such as IP routing, allowing the home user to connect multiple PCs in the home to the Internet at the same time.

DSL allows a concurrent voice call at the same time as allowing an always-on Internet connection. The figure shows an analog phone and a DSL modem connected to a single wall plate with two receptacles. Physically, you connect your DSL modem to a wall socket just like any of the phones in your house. The phone generates an analog signal at frequency ranges between 0 and 4000 Hz; the DSL modem uses frequencies higher than 4000 Hz so that they do not interfere with each other very much. You typically need to put a filter between each phone and the wall socket (not shown) to prevent interference.

The same wiring can be used in the local loop as was used for normal telephone service, but now the CO connects the local loop wiring to a device called a DSLAM. The DSLAM splits the data and voice signals from the local loop. The DSLAM gives the analog voice signal—the frequency range between 0 Hz and 4000 Hz—to a voice switch. The voice switch treats that signal just like any other analog voice line—the switch listens for DTMF tones, creates a circuit, and does PCM encoding to convert the analog signal.

The DSLAM does not pass the data traffic into the PSTN, however. The DSLAM forwards the data traffic to a router owned by the ISP providing the service in this figure. Alternately, the DSLAM can forward the data traffic over an IP network, ultimately reaching a router inside a corporate network.

Notice that the ISP's router actually is depicted as being resident in the local telco's CO—that is true in many cases. However, many people use an ISP that does not happen to be the local telco. To support DSL, the ISP works with the local telco to install some of the ISP's gear in the CO—a process called *co-location*, or *co-lo* for short. The local telco DSLAM forwards and receives the IP packets to and from the ISP router, while the telco maintains control over the local voice traffic.

Typically, the consumer requests high-speed Internet access using DSL from an ISP; the ISP charges the customer for the service, and then the ISP pays the local telco some cut of the fee.

DSL Standards

DSL comes in many flavors to meet different needs. For instance, DSL has limits on how long the local loop can be (the length of the local loop is simply the length of the combined cables that stretch from a house to the CO). Some DSL variants allow the local loop to be much longer, while others allow for only a shorter local loop. For the standards with a shorter local loop, the transmission rates tend to be much higher—a simple design trade-off. ADSL and SDSL tend to be the most popular option in the United States today.

Another architectural difference among the different specifications is that some DSL variants use asymmetric transmission rates, while others use symmetric rates.

Table 15-5 lists the major DSL variants, the standard defining that variant, the speeds, the distance limitations, and encoding.

Table 15-5 *DSL Technologies Standards Comparison*

DSL Type	Standards	Modulation/Encoding Technique	Speed	Distance Limit
Full-rate ADSL/ G.DMT	ANSI T1.413 Issue 2	Discrete multitone (DMT) or carrierless amplitude phase (CAP)	Downstream speed of 384 to 8 Mbps; upstream speed slower, up to 1.024 Mbps	18,000 feet
G.Lite	ITU-T G.992.1, ITU-T G.992.2	DMT	Downstream speed up to 1.544 Mbps to 6 Mbps; upstream speed up to 640 kbps	18,000 feet
Very-high-data-rate DSL (VDSL)	ETSI and ANSI in process	DMT/single-carrier modulation (SCM)	12.96 Mbps to 52.8 Mbps for both upstream and downstream speed	4500 feet
ISDN DSL (IDSL)	ANSI ETR 080	Two binary one quaternary (2B1Q)	144 kbps for both upstream and downstream speed	18,000 feet
Symmetric DSL (SDSL)	None	2B1Q	768 kbps for both upstream and downstream speed	22,000 feet
High-data-rate DSL (HDSL	ITU G.991.1, ANSI TR 28	2B1Q	1.544 or 2.048 Mbps for both upstream and downstream speed	12,000 feet
G.SHDSL	ITU G.991.2	Trellis-coded pulse amplitude modulation (TC PAM)	192 kbps to 2.360 Mbps for both upstream and downstream speed	28,000 feet

A wide variety of standards bodies and vendor consortiums helped develop these standards. As you might imagine, with so many standards, many different organizations pushed for standards that best met their needs. Over time, the number of differing standards will stabilize.

The following organizations are among the key players in the development of DSL:

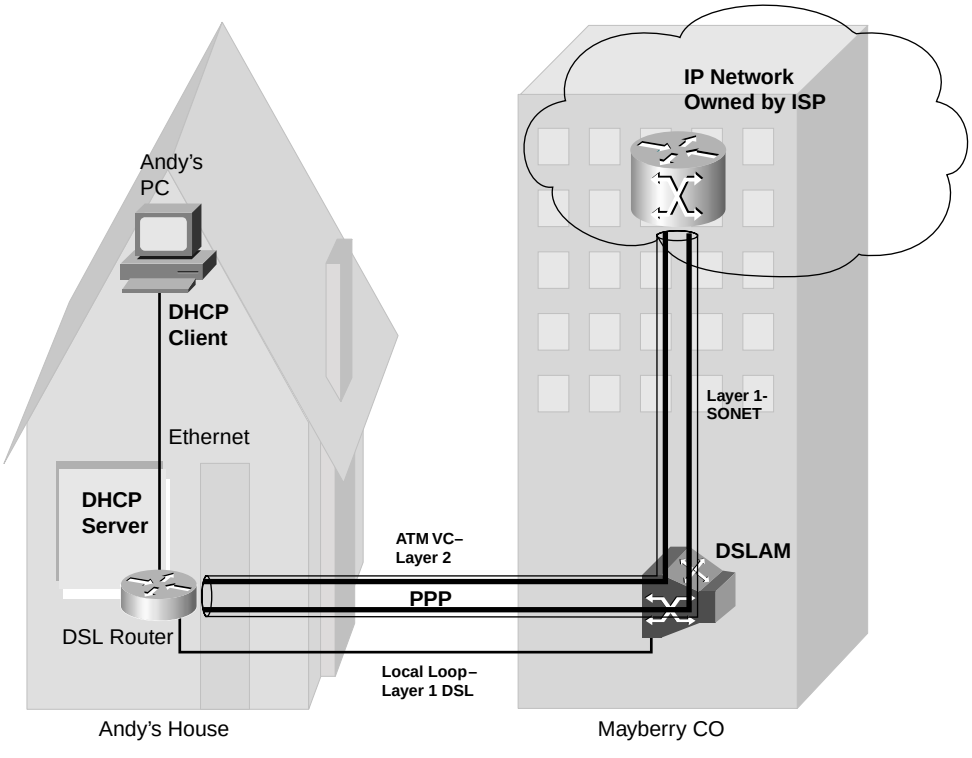
- American National Standards Institute (ANSI)
- Institute of Electrical and Electronics Engineers (IEEE)
- International Telecommunications Union (ITU)
- European Telecommunications Standards Institute (ETSI)
- DSL Forum

DSL Protocols

DSL itself provides a Layer 1 transmission path between two endpoints, in some ways like the Layer 1 service that analog modems and ISDN modems provide. However, DSL uses some additional protocols to support data transfer. For instance, DSL uses ATM as the Layer 2 protocol between the DSL router or DSL modem in the home and the ISP router. Additionally, DSL uses a protocol called PPP over ATM (PPPoA). PPP and ATM are both data-link protocols, but they serve different purposes. PPP provides dynamic address assignment by the ISP for the DSL modem and some basic authentication with Challenge Handshake Authentication Protocol (CHAP). (CHAP is covered in the CCNA ICND Exam Certification Guide and the ICND exam.) Also, depending on the gear installed at a site, DSL might require PPP over Ethernet (PPPoE) for traffic between a PC in the home and the DSL modem/router in the home.

Figure 15-14 shows a typical installation using an ADSL router, like the Cisco 827H series. The 827H acts as both a router and a DSL modem.

Figure 15-14 *Protocols Used with a DSL Router*



Any PCs at the home can connect to the DSL router using Ethernet. In fact, as is common with many DSL routers, the Cisco 827H DSL router includes a four-port Ethernet hub built into the router, so you can just cable a PC directly to the 827H. Alternately, you can create an Ethernet any way you want, as long as there is Ethernet connectivity from the PC to the DSL router. A straight-through Ethernet cable would be used to connect the PC directly to the DSL router.

The PC can be configured just like it would be on any other Ethernet, thinking of the DSL router like any other router. The PC would point to the DSL router's Ethernet IP address as its default gateway. The PC even can use DHCP to acquire an IP address, with the DSL router providing the DHCP server feature.

DSL provides the Layer 1 encoding features for high-speed transmission over the local loop, but it also references ATM as the data-link protocol to use over the DSL link. Back in Chapter 4, "Fundamentals of WANs," you read about the basic features of ATM and SONET, and how ATM sends and receives ATM cells at Layer 2, with SONET providing the Layer 1 transmission details. DSL defines how you can use ATM cells over DSL lines, instead of over SONET, with the ATM cells being forwarded over the DSL connecting from the home to the DSLAM.

The ISP's router needs to receive the data traffic, not the DSLAM in the local CO. So, the DSLAM forwards the ATM cells over the link to the ISP router, probably using an optical cable and Sonet at Layer 1. The receiving ISP router can reassemble the cells and extract the IP packet.

DSL Summary

DSL provides OSI Layer 1 and Layer 2 services to the home. The goal of DSL is to deliver IP packets from the remote user to a router—a router owned by an ISP, or a router resident inside a corporate network. To do so, DSL provides a digital Layer 1 service—serial bit streams in each direction—between the remote site and the local CO. On top of that, DSL uses a combination of ATM, Ethernet, and PPP to help deliver IP packets between the home and a router at an ISP.

DSL brings high-speed remote access capabilities to the home. Depending on the distance to the local CO and the DSL standard supported by the local telco, DSL can support over 1 Mbps. It supports concurrent voice and data, with the data service always being turned on—no dialing is required. And the service speed does not degrade when more users are added to the network.

DSL has some obvious drawbacks. DSL simply will not be available to some people, particular those in rural areas, based on the distance from the home to the CO. The local telco must have DSL equipment in the CO before it, or any ISP, can offer DSL services. Also, even when the home is close enough to the CO, sites farther from the CO might run slower than sites closer to the CO.

Cable Modems

Of all the access technologies covered in this chapter, cable modems are the only one not using a phone line from the local telco for physical connectivity. Many homes also have a cable TV service supplied by an analog electrical signal entering the home over a coaxial cable—in other words, over the cable TV cabling. Cable modems provide an always-on Internet access service, while allowing you to surf the Internet over the cable and make all the phone calls you want over your telephone line—and you can watch TV at the same time!

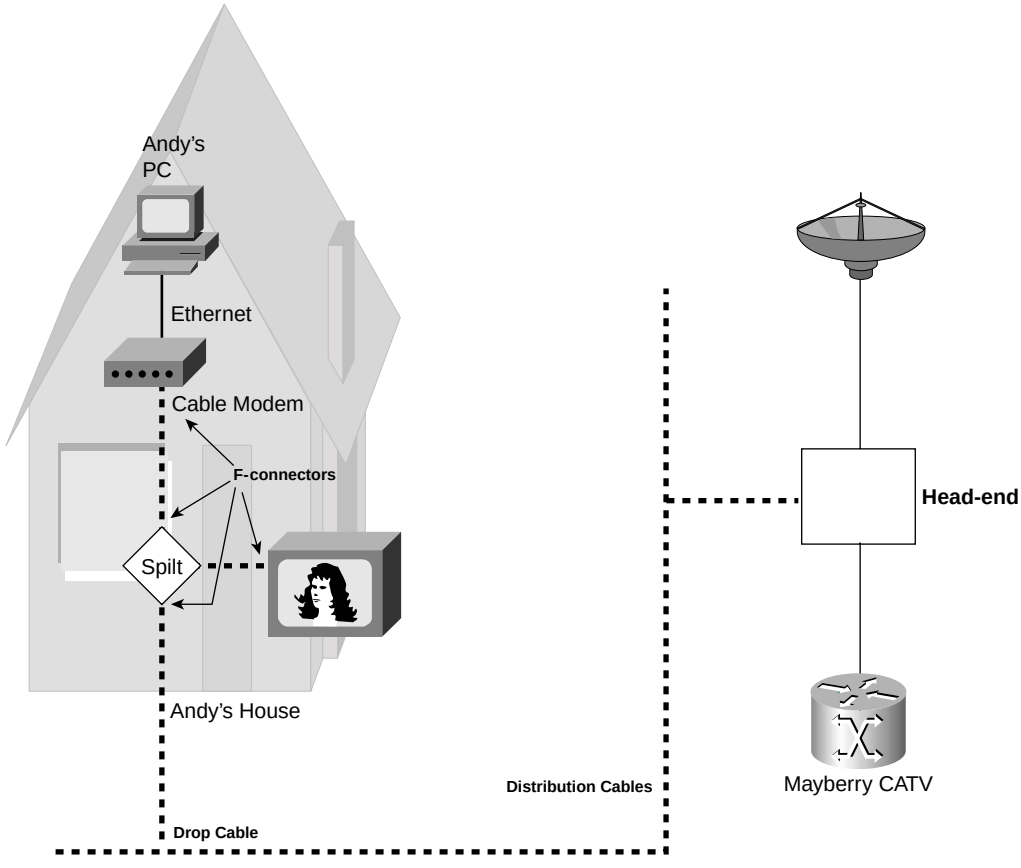
Cable modems use some of the bandwidth that otherwise might have been allocated for new TV channels, using those frequency bands for transferring data. It's a little like having an "Internet" channel to go along with CNN, TBS, ESPN, The Cartoon Network, and all your other favorite cable channels.

To appreciate how cable modems work, you need a little perspective on some cable TV terminology. Cable TV traditionally has been a one-way service—the cable provider sends electrical signals down the cable for all the channels. All you have to do, after the physical installation is complete, is choose the channel you want to watch. While you are watching The Cartoon Network, the electrical signals for CNN still are coming into your house over the cable—your TV is just ignoring that part of the signal. If you have two TVs in your house, you can watch two different channels because the signals for all the channels are being sent down the cable.

Cable TV technology has its own set of terminology, just like most of the other access technologies covered in this chapter. Figure 15-15 outlines some of the key terms.

The *cable head-end site* is a main site that receives the programming. Programming typically is received via a satellite receiver dish. The head end converts the signals to match the correct encoding and frequencies used on the cable and transmits the signals. It also might scramble channels that require an extra fee from subscribers so that you have to get a descrambler—typically called a *set-top box*—from the CATV company.

Figure 15-15 *Cable TV Terminology*



Essentially, the CATV signal is broadcast over the rest of the cable plant, being amplified along the way. A *drop cable* taps into the *distibution cable* that runs near your house and then enters your home and connects to the back of a wall plate near your TV. You just need to run the short coax cable from the back of your TV to the wall plug, and the cabling is complete.

Because most people will want to watch TV as well, possibly multiple TVs, the drop cable must be split. Splitting does not mean literally taking the wire out of the cable and cutting it in half—instead, it means that you use a small device that passively lets the signal coming in from the street pass through to other cables in your house. You can use the same kind of line splitter when using a cable modem that you use when you connect two TVs to the cable TV line at the same time. In the figure, the splitter connects to the drop cable, as well as the two cables connecting to the cable modem and the TV. The splitter just takes the incoming signal

from the drop cable and passes it out both of the other lines. Note that the connector, the round connector common on most CATV cabling, is called an *f-connector*.

When using a cable modem, the CATV company becomes your ISP. Everything between your house and the router at the head end is a single physical and data link. The PC in your home uses a router owned by the cable company, housed at the head-end site, as its default gateway. In fact, the PC typically uses DHCP to discover its IP address and the IP address of its default gateway; the DHCP server would be inside the cable company's IP network, typically at the head-end site.

Conceptually, what happens between the home and the cable head end is similar to a single LAN segment. The details, of course, are different, but the cable installation provides a combination of Layer 1 and Layer 2 protocols to let a PC deliver IP packets to a router inside the cable network. So, as you read about the details of what happens between the home and the router at the head end, keep in mind that the goal is simply to deliver IP packets between the home and the head-end router, and vice versa.

Layer 1 and Layer 2 between the Home and the Head End

Cable TV systems originally were built to send TV video and audio signals to lots of places, with no need to receive a signal back. In other words, the idea of having someone's TV send some information back to the cable company was not even under consideration. Because the original CATV architecture allowed for sending signals from the head end outward, and the capability for two-way communication was added later, data over cable standards treats data going toward the home differently than data coming from the home. In fact, CATV terminology refers to the data going toward the home as *downstream data*, and data from the home as *upstream data*.

Downstream data uses standards that are consistent with some of the standards for sending digital video over cable. In fact, you can think of the downstream data as being sent over another TV channel. For downstream data, the data over cable standards takes advantage of the fact that the signals are broadcast to all subscribers in a section of the cable plant. Just like the TV channels' signals go to every home, the signals for the downstream data go to every home. In many ways, the concepts are similar to an Ethernet broadcast domain: When a broadcast Ethernet frame is sent, everyone in the broadcast domain receives the frame. With downstream cable transmissions, not just broadcast frames, but all data, is broadcast to all receivers. Yes, the data that you receive over the web actually could be captured with a network analysis tool by one of your neighbors.

Because every home in a part of the cable network receives the same data channel, some form of addresses must be used so that only the correct device tries to process incoming data. For

instance, your PC does not need to process any data being sent to your neighbor's PC. So, CATV standards call for the use of a data-link protocol called Multimedia Cable Network Systems (MCNS) MAC. (You might remember that MAC stands for Media Access Control.) MCNS is similar to Ethernet's MAC, as defined in the IEEE 802.3 specification, including the use of Ethernet MAC addresses. So, although all downstream data is sent to all drops in the cable system, only those with a cable modem know that data has been received, and only the PCs with the correct MAC address process the data.

MCNS also defines the physical encoding details. MCNS calls for the use of a modulation method called quadrature amplitude modulation (QAM). Two options can be used for downstream data, one called QAM-64 and the other called QAM-256. QAM-64 represents 6 bits per baud, and QAM-256 represents 8 bits per baud.

Table 15-6 summarizes some of the key reference information about downstream data over cable.

Table 15-6 *Downstream Data over Cable: Interesting Facts*

	Downstream Rate
OSI Layer 1	QAM-64 and QAM-256 encoding
OSI Layer 2	MCNS MAC and IEEE 802.2 LLC
Multiplexing used	Frequency-division multiplexing
Speed	30 to 40 Mbps

Upstream Data

The upstream data channel uses a totally separate frequency range than the downstream channel, so no collisions occur between downstream and upstream data. However, all upstream data from multiple cable subscribers does share the same frequency range—the same channel, essentially—so collisions can occur between data sent toward the Internet by the different home users.

Noticing that a collision has occurred in an upstream cable channel is much more difficult than with an Ethernet. Cables inside the CATV cable plant might be miles long, which means that a device would have to wait longer for the electrical signal from a collision to return. So, the CSMA/CD algorithm used by Ethernet does not work well on the upstream channel. Instead, MCNS defines the use of a multiplexing method called time-division multiple access (TDMA), in which each home user is granted regular time periods during which to send upstream data. These time slots happen multiple times per second. By using TDMA, most collisions can be avoided.

The upstream channel uses the same data-link protocols as the downstream channel, with MAC addressing, but it uses different modulation schemes. The upstream channel uses quaternary phase-shift keying (QPSK) or QAM-16. QPSK modulates the signal using phase shifts, while QAM uses amplitude modulation.

Both the downstream and upstream channels compete with other users for the use of the channel. So, as more subscribers are added, the actual throughput of the connection actually can slow down.

Table 15-7 summarizes some of the key points about the upstream data channel.

Table 15-7 *Upstream Data over Cable: Interesting Facts*

	Downstream Rate
OSI Layer 1	QPSK and QAM-16
OSI Layer 2	MCNS MAC and IEEE 802.2 LLC
Multiplexing used	Time-division multiple access (TDMA)
Speed	320 kbps to 10 Mbps

Cable Modem Summary

Like DSL, cable modems bring high-speed remote access capabilities to the home. The speeds might seem astounding—30 to 40 Mbps downstream is indeed impressive. In fact, I had a cable modem a few years ago and was one of the first people in my neighborhood to get it. I surfed the web much faster from home than I did from the local Cisco Systems office! The data service is always on, even when someone is watching TV. Because it doesn't use the telephone line at all, you also can use the phone at the same time.

Cable modems do have a few drawbacks. The per-user data rates degrade as more users are added to the network. Also, because the network broadcasts all downstream traffic, anyone can put a network-analysis tool in their home and get a copy of what their neighbor is receiving.

Comparison of Remote Access Technologies

This chapter scratches the surface of how modems, ISDN, cable, and DSL work. Consumers choose between these options for Internet access all the time, and network engineers choose between these options for supporting their work-at-home users as well. So, it seems appropriate to close the chapter by listing some of the key comparison points for these options.

The remote access technologies in this chapter provide services at Layer 1, and possibly Layer 2, of the OSI reference model. TCP/IP and all the associated higher-layer protocols (TCP, UDP, HTTP, FTP, Telnet, DNS, DHCP, and so on) can run over any of these access technologies; the differences lie in what is done at Layers 1 and 2. Figure 15-16 outlines the protocols used by each.

Figure 15-16 *The OSI Reference Model and Remote Access Technologies*

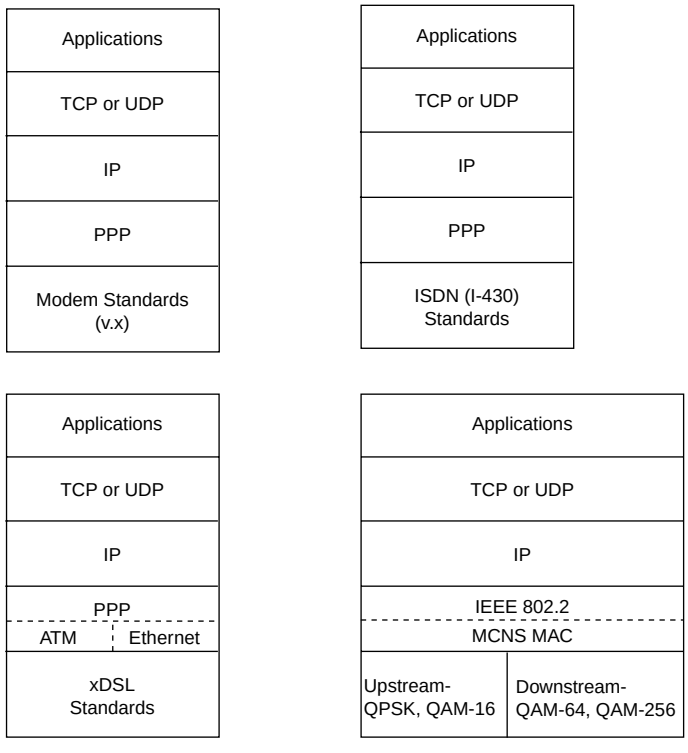


Table 15-8 lists some of the main points for comparison of these technologies.

Table 15-8 *Comparison of Modems, ISDN, DSL, and Cable*

	Analog Modems	ISDN	DSL	Cable Modems
Transport	Telco line	Telco line	Telco line	CATV cable
Supports symmetric speeds?	Yes	Yes	Yes	No
Supports asymmetric speeds?	Yes	No	Yes	Yes
Speed ranges	56 kbps and lower	64 kbps per B channel	56 kbps to 2 Mbps	320 kbps to 40 Mbps

continues

Table 15-8 *Comparison of Modems, ISDN, DSL, and Cable (Continued)*

	Analog Modems	ISDN	DSL	Cable Modems
Degrades under higher loads?	No	No	No	Yes
Supports IP and associated higher-layer protocols?	Yes	Yes	Yes	Yes
Allows concurrent voice and data?	No	Yes	Yes	Yes
Always on?	No	No	Yes	Yes
Local loop distance issues	No	No	Yes; distance varies	No

Foundation Summary

The "Foundation Summary" section of each chapter lists the most important facts from the chapter. Although this section does not list every fact from the chapter that will be on your CCNA exam, a well-prepared CCNA candidate should know, at a minimum, all the details in each "Foundation Summary" section before going to take the exam.

Figure 15-17 depicts the PSTN and how it supports analog voice through a digital T1 core.

Figure 15-17 *Analog Voice Calls Through a Digital PSTN*

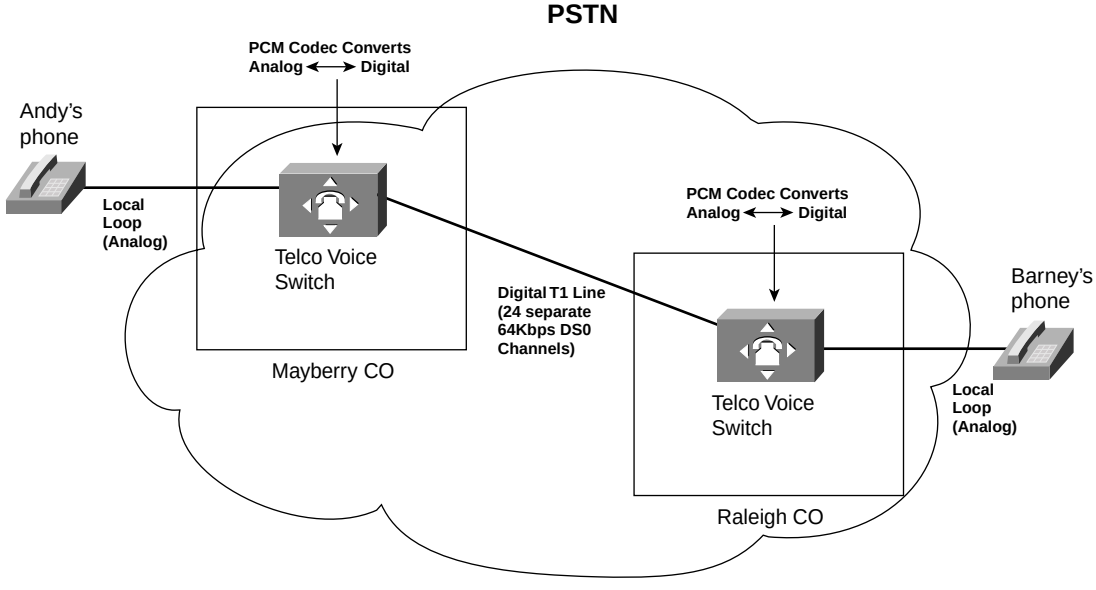


Table 15-9 lists some of the key modem standards.

Table 15-9 *Modem Standards*

Standard	Speed	Comments
V.22	1200 bps (600 baud)	Mainly used outside the United States
V.22bis*	2400 bps (600 baud)	First widely deployed worldwide standard
V.32	4800/9600 (2400 baud)	Adjusts speed based on line quality
V.32bis*	14.4kbps (2400 baud)	Backward compatible with V.32

continues

Table 15-9 *Modem Standards (Continued)*

Standard	Speed	Comments
V.34	28.8 kbps	Backward compatible with V.32bis and V.32
V.42	28.8 kbps	Same speed as V.34, but with error-correction features
V.90	56 kbps (downstream), 33 kbps (upstream)	Created from two earlier competing standards, X2 and K56Flex
V.92	56 kbps/33 kbps (downstream/upstream) or 48 kbps (each direction)	Connects and finds correct speed more quickly than V.90; allows "modem-on-hold"

*"bis" simply means "version 2."

Figure 15-18 shows the typical topology with ISDN in use for access to an ISP.

Figure 15-18 *ISDN Local Loops and Equipment*

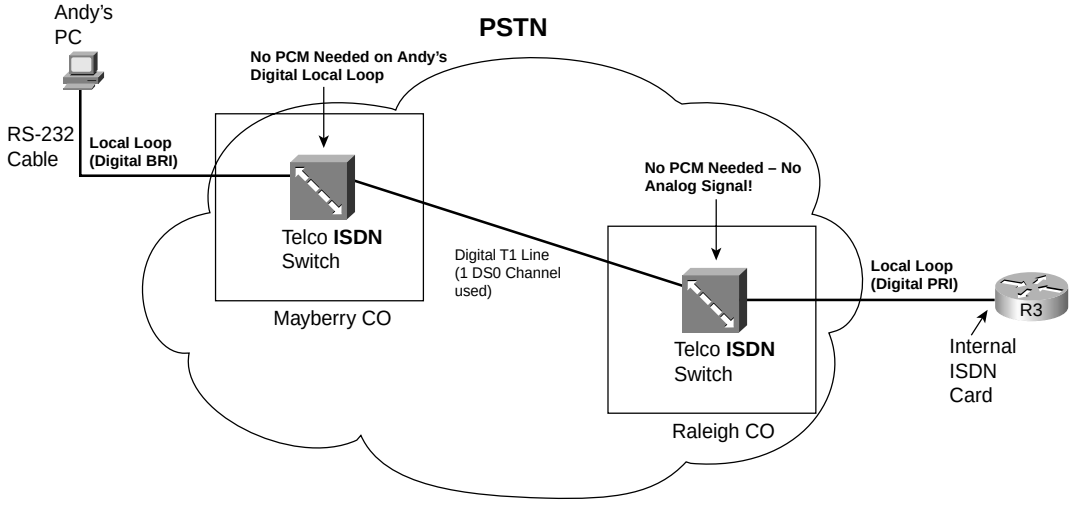


Table 15-10 lists the number of channels for each type of ISDN line and the terminology used to describe them.

Table 15-10 *BRI and PRI B and D Channels*

Type of Interface	Number of Bearer Channels (B Channels)	Number of Signaling Channels (D Channels)	Descriptive Term
BRI	2	1 (16 kbps)	2B+D
PRI (T1)	23	1 (64 kbps)	23B+D
PRI (E1)	30	1 (64 kbps)	30B+D

Figure 15-19 shows some of the detail of a typical DSL connection.

Figure 15-19 *DSL Connection from the Home*

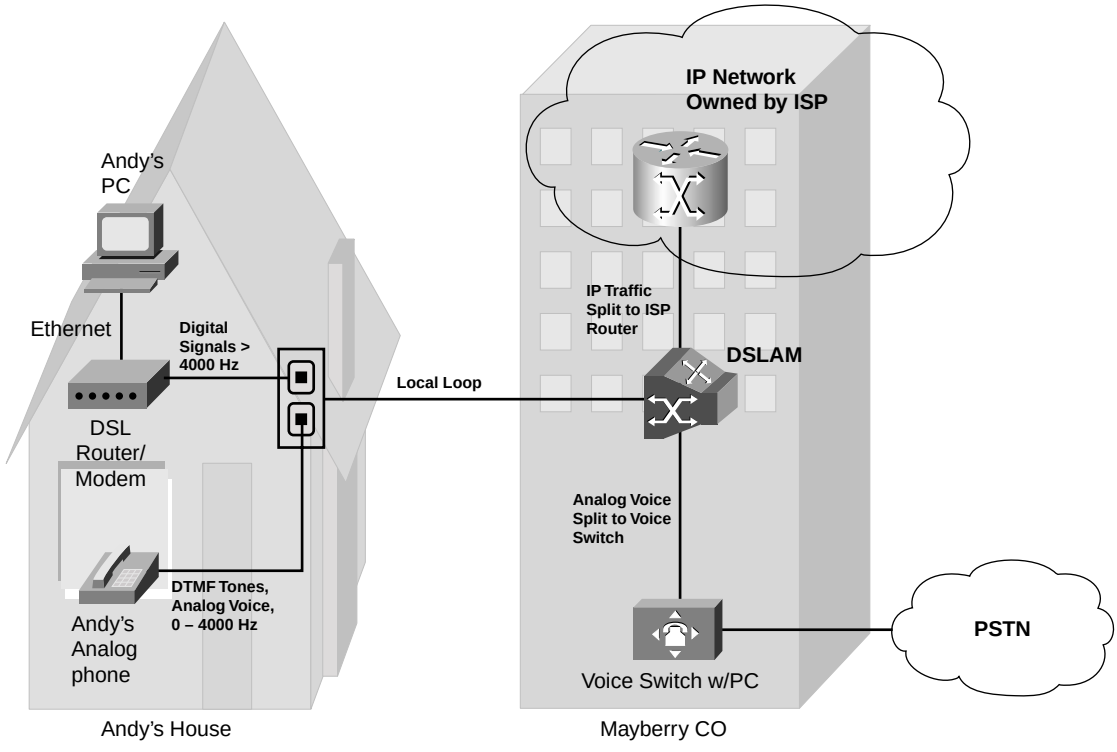


Table 15-11 lists the major DSL variants, the standard defining that variant, the modulation/encoding technique, speed, and distance limitations.

Table 15-11 *DSL Technologies Standards Comparison*

DSL Type	Standards	Modulation/Encoding Technique	Speed	Distance Limit
Full-rate ADSL/G.DMT	ANSI T1.413 Issue 2	Discrete multitone (DMT) or carrierless amplitude phase (CAP)	Downstream speed of 384 to 8 Mbps; upstream speed slower, up to 1.024 Mbps	18,000 feet
G.Lite	ITU-T G.992.1, ITU-T G.992.2	DMT	Downstream speed up to 1.544 Mbps to 6 Mbps; upstream speed up to 640 kbps	18,000 feet

continues

Table 15-11 *DSL Technologies Standards Comparison (Continued)*

DSL Type	Standards	Modulation/Encoding Technique	Speed	Distance Limit
Very-high-data-rate DSL (VDSL)	ETSI and ANSI in process	DMT/single-carrier modulation (SCM)	12.96 Mbps to 52.8 Mbps for both upstream and downstream speed	4500 feet
ISDN DSL (IDSL)	ANSI ETR 080	Two binary one quaternary (2B1Q)	144 kbps for both upstream and downstream speed	18,000 feet
Symmetric DSL (SDSL)	None	2B1Q	768 kbps for both upstream and downstream speed	22,000 feet
High-data-rate DSL (HDSL	ITU G.991.1, ANSI TR 28	2B1Q	1.544 or 2.048 Mbps for both upstream and downstream speed	12,000 feet
G.SHDSL	ITU G.991.2	Trellis-coded pulse amplitude modulation (TC PAM)	192 kbps to 2.360 Mbps for both upstream and downstream speed	28,000 feet

Figure 15-20 outlines some of the key terms used with CATV.

Figure 15-20 *Cable TV Terminology*

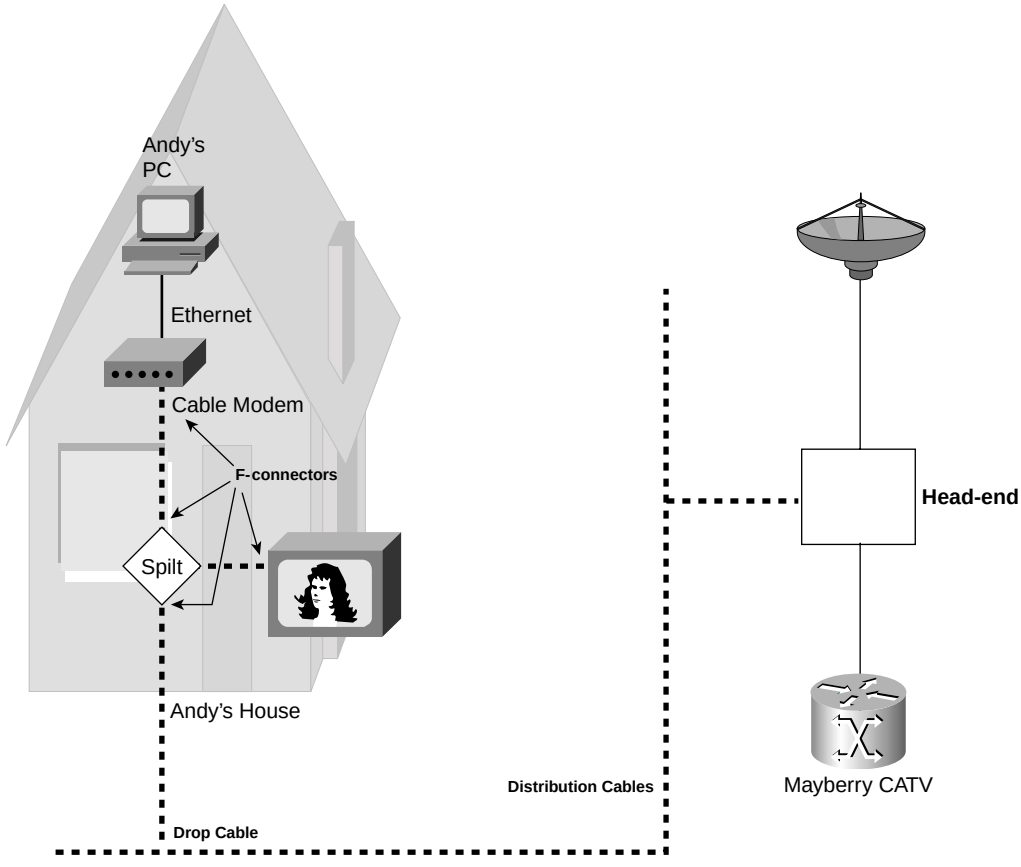


Table 15-12 summarizes some of the key reference information about downstream CATV data over cable.

Table 15-12 *Downstream Data over Cable: Interesting Facts*

	Downstream Rate
OSI Layer 1	QAM-64 and QAM-256 encoding
OSI Layer 2	MCNS MAC and IEEE 802.2 LLC
Multiplexing used	Frequency-division multiplexing
Speed	30 to 40 Mbps

Table 15-13 summarizes some of the key points about the upstream CATV data channel.

Table 15-13 *Upstream Data over Cable: Interesting Facts*

	Downstream Rate
OSI Layer 1	QPSK and QAM-16
OSI Layer 2	MCNS MAC and IEEE 802.2 LLC
Multiplexing used	Time-division multiple access (TDMA)
Speed	320 kbps to 10 Mbps

The remote access technologies in this chapter provide services at Layer 1, and possibly Layer 2, of the OSI model. TCP/IP and all the associated higher-layer protocols (TCP, UDP, HTTP, FTP, Telnet, DNS, DHCP, and so on) can run over any of these access technologies; the differences lie in what is done at Layers 1 and 2. Figure 15-21 outlines the protocols used by each.

Figure 15-21 *The OSI Model and Remote Access Technologies*

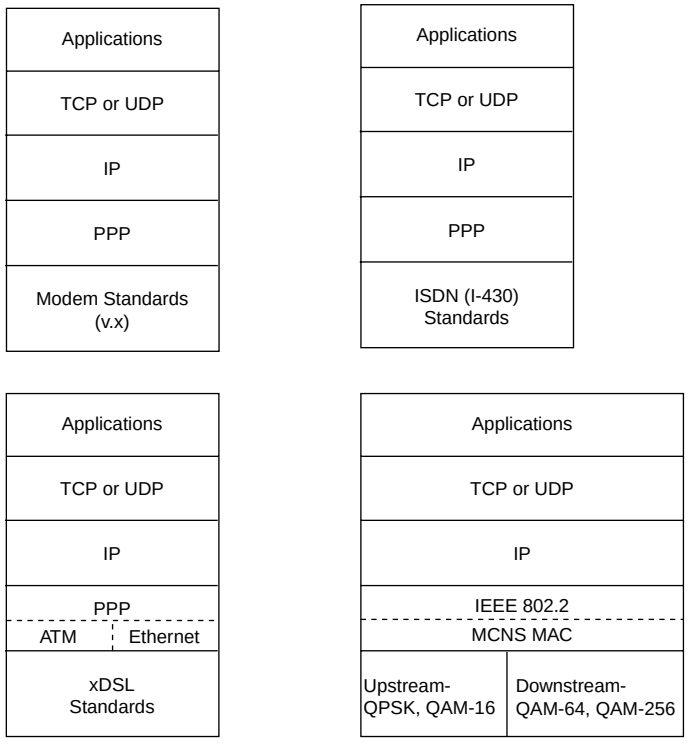


Table 15-14 lists some of the main points for comparison of these technologies. Comparison points are always good material for exam questions.

Table 15-14 *Comparison of Modems, ISDN, DSL, and Cable*

	Analog Modems	ISDN	DSL	Cable Modems
Transport	Telco line	Telco line	Telco line	CATV cable
Supports symetric speeds?	Yes	Yes	Yes	No
Supports asymmetric speeds?	Yes	No	Yes	Yes
Speed ranges	Less than 56 kbps	64 kbps per B channel	56 kbps to 2 Mbps	320 kbps to 40 Mbps
Degrades under higher loads?	No	No	No	Yes
Supports IP and associated higher-layer protocols?	Yes	Yes	Yes	Yes
Allows concurrent voice and data?	No	Yes	Yes	Yes
Always on?	No	No	Yes	Yes
Local loop distance issues	No	No	Yes; distance varies	No

Q&A

As mentioned in the introduction, you have two choices for review questions. The questions that follow give you a bigger challenge than the exam itself by using an open-ended question format. By reviewing now with this more difficult question format, you can exercise your memory better and prove your conceptual and factual knowledge of this chapter. The answers to these questions are found in Appendix A.

For more practice with exam-like question formats, including questions using a router simulator and multiple-choice questions, use the exam engine on the CD.

1. What do ISDN, BRI, and PRI stand for?
2. How many bearer channels are in a BRI? What about a PRI in North America? What about a PRI in Europe?
3. Define what a voice codec does, and explain why a PCM codec needs 64 kbps for a single voice call.
4. Two terms were shortened and combined to first create the word modem. Identify those two words and describe what each word means.
5. Define what the terms symmetric and asymmetric mean in relation to modem specifications. Also explain why asymmetric might be a better option.
6. Compare the V.90 and V.92 modem specifications.
7. Compare analog modems, ISDN BRIs, DSL, and cable modems in terms of concurrent support for voice and data.
8. Compare analog modems, ISDN BRIs, DSL, and cable modems in terms of whether the data service is always on.
9. List some of the pros and cons regarding the use of analog modems for remote access.
10. List some of the pros and cons regarding the use of ISDN for remote access.
11. List some of the pros and cons regarding the use of DSL for remote access.
12. Define what the acronym DSLAM stands for, and explain the concept behind how a DSLAM allows voice and data to flow over the same local loop phone line.
13. Which of the DSL standards is the most common in the United States today? What is the range of upstream and downstream speeds for that type of DSL, as well as the maximum distance of the local loop?

14. What protocols are used by DSL at the data link layer?

15. Imagine that Andy and Barney are neighbors, and they both use cable modems. Describe the type of traffic that they could generate that could cause collisions, and tell what is done to help prevent those collisions.

16. Name the four different Layer 1 encoding methods defined for use by cable modems. For each one, list whether it is used for upstream data, downstream data, or both.

17. Which of the four different remote access technologies support IP, TCP, UDP, and the rest of the higher-layer TCP/IP protocols?

18. Compare and contrast the cabling used by an analog modem and a DSL router/modem when connecting to the local phone company line. Identify the purpose of each pin on the connector.

19. Compare and contrast the cabling used by an ISDN modem and a cable modem when connecting to the local phone company line or cable drop line. Identify the purpose of each pin on the connector.

20. List four standards bodies that have been involved in the development of DSL standards.

PART VI: Final Preparation

Chapter 16: Final Preparation

CHAPTER 16

Final Preparation

So, you have made it through most of the book, and you have probably either scheduled your INTRO exam or CCNA exam, or at least thought about when you want to try to take it. Congratulations for getting this far! You will soon have finished your first step toward building your networking career résumé.

This chapter provides some tips on your final preparation for the exam. It also provides an example scenario, which helps you to pull many of the hands-on skills together into a single review section.

Suggestions for Final Preparation

Everyone has their own study habits, and you should know what works well for you. However, here are a few suggestions you can try in the week or two before you take the exam:

- Reread the "Foundation Summary" sections of each chapter.
- When reviewing tables and definitions, you should cover up portions of summary tables with a piece of paper, forcing yourself to try to remember the details instead of just glancing at them.
- Answer all the questions from inside the book again. You should strive to master these questions so that you can answer the questions quickly.
- If you are still slow in answering subnetting questions, practice until you can find the subnet number and broadcast address when the mask is "difficult" within 1 minute. You can use the CD-based chapter with 25 subnetting practice questions for this exercise.
- Before using the CD for general questions, use the mode that lets you perform a simulated exam. This will help you prepare for the exam experience.
- Repeat answering all the questions on the CD until you can answer most of them almost automatically.

- Using a real set of routers and switches, or using a simulation product (such as Netsim, which is included on the accompanying CD), practice these basic skills:
  - Accessing a switch and a router
  - Configuring basic administrative settings (passwords, host name, IP addresses)
  - Practice configuring IP, static routes, and RIP
  - Refer to Appendix C for a list of labs from this book that can be performed using the NetSim simulator that is included on the accompanying CD.

Preparing for the Actual Exam Experience

For some of you, either the INTRO exam or the CCNA exam will be your first experience with a proctored computer-based exam for Cisco certification. Do not be alarmed—it's not terribly different than using the exam software on the CD that came with the book. However, you should go into the exam day with the following in mind:

- You typically need two forms of ID, at least one of which is a picture ID. A driver's license, a passport, and a military ID are all valid.
- The testing center is probably just an extra room inside the offices of a company that does something else for its primary business. Often training companies are also testing centers. The proctor usually has other responsibilities besides monitoring the exams. The proctor seldom enters the testing room, other than to bring in another person who has an exam scheduled. So, do not worry about someone staring at you and making you nervous. However, most testing centers do have video cameras for monitoring—just because you cannot see them, it does not mean that they are not watching.
- You will need to turn off all electronics that you bring with you—phone, pager, and secret decoder rings. I typically just leave them in the car. They may ask you to leave your pager or phone at the front desk as well.
- You cannot bring any of your own paper into the room, either. The proctor will give you something to write on, either paper or a dry-erase board and marker. In either case, you should return these to the proctor when you are done.
- You will take the exam using a PC. The proctor will start the software for you; all you have to do is follow the instructions. You will not be forced to start the exam the instant that you sit down because you will typically be allowed to take a four- to five-question practice test. The practice exam asks you questions in different formats about a totally unrelated topic, just to let you get used to the interface. Cisco often adds an optional

survey before the exam as well, just to gather demographic information about who is taking the exam. If you've never taken a Cisco exam, take the extra few minutes to take the practice test, just to get completely comfortable with the environment.

- You can actually write on your scratch paper before the exam begins, if you like. For instance, some people like to write down the list of all the valid subnet masks, the corresponding prefixes, and possibly even the binary equivalents for the decimal numbers used inside subnet masks. I've heard of some people writing down hard-to-memorize information that they were cramming for in the lobby of the testing center! Personally, I do not find it helpful to write down the hard-to-memorize things right before the exam begins, but for some people, it does help. Many people find it helpful to write down the subnetting information just mentioned.
- The exam engine does not let you go back and change an earlier answer. So, read each question thoroughly and read every answer thoroughly. When you move on to the next question, you can't go back.
- Some questions require that you drag and drop the answers into the correct slots in an answer area. Exam question writers like to use this type of question for lists or sequences in particular. Like all questions, you can answer and then change the answer, as long as you have not moved on to the next question yet. For drag-and-drop questions, many people benefit from moving the answers they are confident about into the (presumably) correct place, and then they fit in the others in; a lot of times, that helps complete the answers correctly. Just don't forget, when you move on to the next question, you can't go back!
- For simulated lab questions, you should go back and confirm that any new configurations are working. For instance, if the question asks that you configure RIP, but you do not see any routes when you use a **show ip route** command, then you have not finished the question correctly. The simulator used on the exam does work so that the **show** commands reflect what should actually be happening. Many of the simulated lab questions require that you configure something, but it will also be helpful if you know the pertinent **show** commands to verify the correct operation. Also, just for good measure, save your configuration unless the question tells you not to.

That's a long list, but hopefully it will help you prepare for taking the exam. The most important tip is to simply relax. A good night's rest is better than a night full of cramming for most people.

The following list gives a short reminder of the things you might want to keep in mind as you prepare to walk in the door at the testing center:

- Bring two pens.
- Bring two IDs, one with a picture.
- Turn off your electronics before going to the exam room.
- Relax!

A Final Lab Scenario

The current CCNA exams include simulated lab questions. The best way to prepare for those is to work with live networks using Cisco routers and switches. You should also make sure to do all the questions in the testing engine on the CD, as it contains a large number of simulated lab questions. You can also use the NetSim network simulator on the CD, or rent time via online labs.

Regardless of how much time and effort you spend with hands-on practice, the following lab scenario can help you with your final preparation if you simply read through the scenario. Throughout the book, the portions that covered how to do something on a switch or a router focused on the specific topics covered in that chapter. The scenario in this chapter touches on many of the topics in this book that are in some way related to configuration or operation of a router or switch. So, you can use this scenario as part of your strategy for final preparation for the exam.

If you have enough time, review all the parts of the scenario. If you have time, try to perform all the tasks outlined in Steps A, B, and C. However, if you have limited time, you might want to review the problem statements and then review the answers for each of the three parts. At least you will get a good review of some of the more important commands that could be on the exam.

If you are reading this chapter as your final review before taking the exam, let me take this opportunity to wish you success. Hopefully, you will be relaxed and confident for your exam—and hopefully, this book will have helped you build your knowledge and confidence.

Scenario, Part A: Planning

This scenario has three parts, listed as Parts A, B, and C. Part A begins with some planning guidelines that mainly consist of planning an IP addressing scheme for a network. After you complete Part A, Part B of the scenario asks you to configure the three routers and one switch to implement the planned design. Finally, Part C asks you to examine router command output and answer questions about the details of current operation of the network. Part C also lists some questions related to the user interface and protocol specifications.

Your job is to deploy a new network with three sites, as shown in Figure 16-1. The decision to use point-to-point serial links has already been made, and the products have been chosen. For Part A of this scenario, perform the following tasks:

1. Plan the IP addressing and subnets used in this network. Class B network 163.1.0.0 has been assigned by the NIC. The maximum number of hosts per subnet is 100.
2. Assign IP addresses to the PCs as well.
3. Assign addresses for the switches near R1 for management purposes.

Assume that a single VLAN is used on the switches near Router 1 (R1).

Tables 16-1 and 16-2 are provided as a convenient place to record your IP subnets and IP addresses when performing the planning tasks for this scenario.

Figure 16-1 *Scenario Network Diagram*

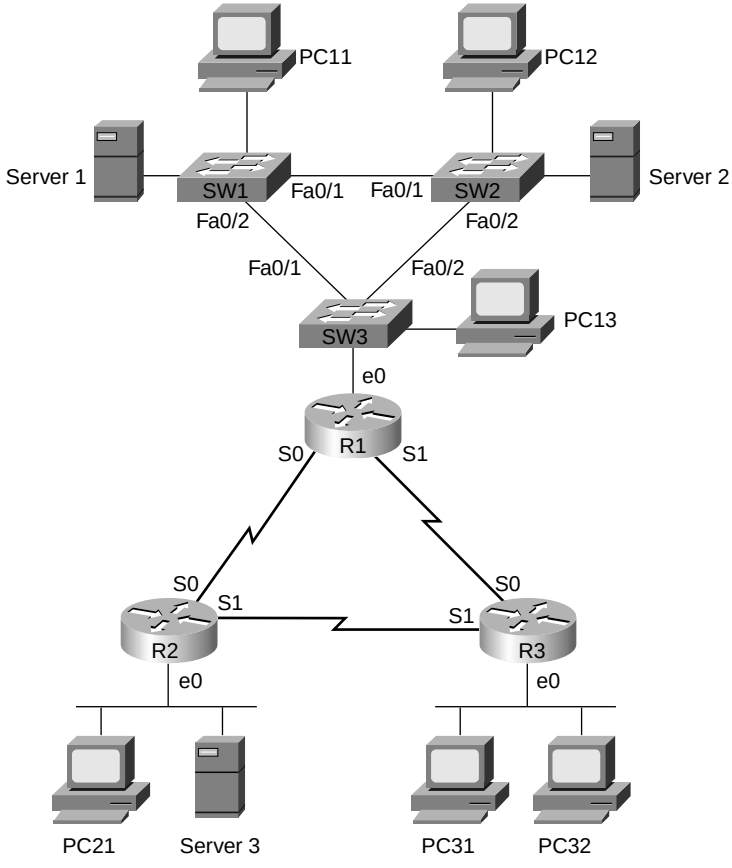


Table 16-1 *Part A: IP Subnet and IP Address Planning Chart*

Location of Subnet/Network Geographically	Subnet Mask	Subnet Number
R1 Ethernet		
R2 Ethernet		
R3 Ethernet		
Serial between R1 and R2		
Serial between R1 and R3		
Serial between R2 and R3		

Table 16-2 *Part A: IP Address Planning Chart*

Host	Address
PC11	
PC12	
PC13	
PC21	
PC31	
PC32	
SW1	
SW2	
SW3	
R1–E0	
R1–S0	
R1–S1	
R2–E0	
R2–S0	
R2–S1	
R3–E0	
R3–S0	
R3–S1	
Server 1	
Server 2	
Server 3	

Solutions to Part A: Planning

It's a good idea to keep the design as simple as possible, without making it so simple that it will not be useful as the network evolves. In this case, any subnet mask with at least 7 host bits would work, including the easy mask of 255.255.255.0. Any choice of mask between 255.255.224.0 and 255.255.255.128 would have allowed for 6 subnets and 100 hosts per subnet.

Table 16-3 shows one solution for the subnet numbers chosen, using mask 255.255.255.128, with Table 16-4 showing some sample IP address assignments.

Table 16-3 *Part A: The Completed IP Subnet Planning Chart*

Location of Subnet/Network Geographically	Subnet Mask	Subnet Number
R1 Ethernet	255.255.255.128	163.1.1.128
R2 Ethernet	255.255.255.128	163.1.2.128
R3 Ethernet	255.255.255.128	163.1.3.128
Serial between R1 and R2	255.255.255.128	163.1.12.128
Serial between R1 and R3	255.255.255.128	163.1.13.128
Serial between R2 and R3	255.255.255.128	163.1.23.128

Table 16-4 *Part A: The Completed IP Address Planning Chart*

Host	Address
PC11	163.1.1.211
PC12	163.1.1.212
PC13	163.1.1.213
PC21	163.1.2.221
PC31	163.1.3.231
PC32	163.1.3.232
SW1	163.1.1.211
SW2	163.1.1.212
SW3	163.1.1.213
R1–E0	163.1.1.201
R1–S0	163.1.12.201
R1–S1	163.1.13.201
R2–E0	163.1.2.202
R2–S0	163.1.12.202

continues

Table 16-4 *Part A: The Completed IP Address Planning Chart (Continued)*

Host	Address
R2–S1	163.1.23.202
R3–E0	163.1.3.203
R3–S0	163.1.13.203
R3–S1	163.1.23.203
Server 1	163.1.1.1
Server 2	163.1.1.2
Server 3	163.1.2.3

As long as the numbers are in the right subnet, the actual IP addresses that you chose for your answer are fine. I just picked numbers between 200 and 209 for the last octet for router addresses, and between 210 and 239 for the switches and PCs. For the servers, I made the last octet match the server number. In real networks, you might reserve particular ranges of last octet values in each subnet for network overhead devices. For instance, all of your routers' LAN interface IP addresses might always be between 1 and 5.

Scenario Part B: Configuration

The next step in your job is to deploy the network designed in Part A. Perform the following tasks:

1. Configure IP addresses based on the design from Part A.
2. Although this book did not cover RIP configuration, assume that someone else who knows how to configure RIP will configure the routers to support RIP.
3. Use PPP as the data-link protocol on the link between R2 and R3. Use the default serial encapsulation elsewhere.
4. Configure basic administrative settings for SW3, assuming that it is a 2950 series switch. Set the host name, IP address, default gateway, enable password, telnet password, and console password. Save the configuration as well.

Solutions to Part B: Configuration

Examples 16-1, 16-2, 16-3, and 16-4 show the configurations for Part B.

Example 16-1 *R1 Configuration*

```
hostname R1
!
interface Serial0
```

Example 16-1 *R1 Configuration (Continued)*

```
 ip address 163.1.12.201 255.255.255.128
!
interface Serial1
 ip address 163.1.13.201 255.255.255.128
!
Ethernet0
 ip address 163.1.1.201 255.255.255.128
!
router rip
network 163.1.0.0
```

Example 16-2 *R2 Configuration*

```
hostname R2
!
interface Serial0
 ip address 163.1.12.202 255.255.255.128
!
interface Serial1
 encapsulation ppp
 ip address 163.1.23.202 255.255.255.128
!
Ethernet0
 ip address 163.1.2.202 255.255.255.128
!
! the following 2 commands configure RIP.
!
router rip
network 163.1.0.0
```

Example 16-3 *R3 Configuration*

```
hostname R3
!
interface Serial0
 ip address 163.1.13.203 255.255.255.128
!
interface Serial1
 encapsulation ppp
 ip address 163.1.23.203 255.255.255.128
!
Ethernet0
 ip address 163.1.3.203 255.255.255.128
!
router rip
network 163.1.0.0
```

Example 16-4 *SW3 Configuration*

```
Switch>enable
Switch#configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)#hostname SW3
SW3(config)#enable secret cisco
SW3(config)#line vty 0 15
SW3(config-line)#password cisco
SW3(config-line)#login
SW3(config-line)#line con 0
SW3(config-line)#login
% Login disabled on line 0, until 'password' is set
SW3(config-line)#password cisco
SW3(config-line)#interface vlan 1
SW3(config-if)#ip address 163.1.1.213 255.255.255.128
SW3(config-if)#no shutdown
SW3(config-if)#exit
SW3(config)#ip default-gateway 163.1.1.201
SW3(config)#interface fastEthernet 0/1
SW3(config-if)#description trunk to SW1
SW3(config-if)#interface fastethernet 0/2
SW3(config-if)#description trunk to SW2
SW3(config-if)#^Z
SW3#
SW3#copy running-config startup-config
Destination filename [startup-config]?
Building configuration...
[OK]
SW3#
```

Scenario Part C: Verification and Questions

The INTRO exam tests you on your memory of the kinds of information you can find in the output of various **show** commands. Using Examples 16-5, 16-6, and 16-7 as references, answer the questions following the examples.

> **NOTE** In the network from which these commands were captured, several administrative settings not mentioned in the scenario were configured. For example, the enable password was configured. So, the configurations might contain additional items not specifically mentioned in the instructions, but none of those impact the actual behavior of the features discussed in the scenario.

Example 16-5 *Scenario Part C: R1* **show** *and* **debug** *Output*

```
R1#show ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
Serial0                163.1.12.201    YES NVRAM  up                    up
Serial1                163.1.13.201    YES NVRAM  up                    up
Ethernet0              163.1.1.201     YES NVRAM  up                    up
R1#show access-lists
Standard IP access list 83
    deny   163.1.3.0, wildcard bits 0.0.0.127
    permit any
R1#
```

Example 16-6 *Part C: R2* **show** *and* **debug** *Output*

```
R2#show interface
Serial0 is up, line protocol is up
  Hardware is HD64570
  Internet address is 163.1.12.202/25
  MTU 1500 bytes, BW 1544 Kbit, DLY 20000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation HDLC, loopback not set
  Keepalive set (10 sec)
  Last input never, output never, output hang never
  Last clearing of "show interface" counters never
  Input queue: 0/75/0/0 (size/max/drops/flushes); Total output drops: 0
  Queueing strategy: weighted fair
  Output queue: 0/1000/64/0 (size/max total/threshold/drops)
     Conversations  0/0/256 (active/max active/max total)
     Reserved Conversations 0/0 (allocated/max allocated)
     Available Bandwidth 1158 kilobits/sec
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
     1242 packets input, 98477 bytes, 0 no buffer
     Received 898 broadcasts, 0 runts, 0 giants, 0 throttles
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
     1249 packets output, 91395 bytes, 0 underruns
     0 output errors, 0 collisions, 2 interface resets
     0 output buffer failures, 0 output buffers swapped out
     12 carrier transitions
     DCD=up  DSR=up  DTR=up  RTS=up  CTS=up
Serial1 is up, line protocol is up
  Hardware is HD64570
  Internet address is 163.1.23.202/25
    MTU 1500 bytes, BW 1544 Kbit, DLY 20000 usec,
       reliability 255/255, txload 1/255, rxload 1/255
    Encapsulation PPP, loopback not set
    Keepalive set (10 sec)
    LCP Open
```

continues

Example 16-6 *Part C: R2* **show** *and* **debug** *Output (Continued)*

```
    Open: IPCP, CDPCP
    Last input 00:00:03, output 00:00:03, output hang never
    Last clearing of "show interface" counters 00:00:15
    Input queue: 0/75/0/0 (size/max/drops/flushes); Total output drops: 0
    Queueing strategy: weighted fair
    Output queue: 0/1000/64/0 (size/max total/threshold/drops)
       Conversations  0/1/256 (active/max active/max total)
       Reserved Conversations 0/0 (allocated/max allocated)
       Available Bandwidth 1158 kilobits/sec
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
     1654 packets input, 90385 bytes, 0 no buffer
     Received 1644 broadcasts, 0 runts, 0 giants, 0 throttles
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
     1674 packets output, 96130 bytes, 0 underruns
     0 output errors, 0 collisions, 8 interface resets
     0 output buffer failures, 0 output buffers swapped out
     13 carrier transitions
     DCD=up  DSR=up  DTR=up  RTS=up  CTS=up
Ethernet0 is up, line protocol is up
  Hardware is MCI Ethernet, address is 0000.0c89.b170 (bia 0000.0c89.b170)
  Internet address is 163.1.2.202, subnet mask is 255.255.255.128
    MTU 1500 bytes, BW 10000 Kbit, DLY 1000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation ARPA, loopback not set, keepalive set (10 sec)
  ARP type: ARPA, ARP Timeout 4:00:00
Last input 00:00:00, output 00:00:04, output hang never
  Last clearing of "show interface" counters never
  Queuing strategy: fifo
  Output queue 0/40, 0 drops; input queue 0/75, 0 drops
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
     2274 packets input, 112381 bytes, 0 no buffer
     Received 1913 broadcasts, 0 runts, 0 giants, 0 throttles
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
     863 packets output, 110146 bytes, 0 underruns
     0 output errors, 0 collisions, 2 interface resets
     0 output buffer failures, 0 output buffers swapped out
     6 transitions

R2#show ip protocol
Routing Protocol is "rip"
  Sending updates every 30 seconds, next due in 6 seconds
  Invalid after 180 seconds, hold down 180, flushed after 240
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Redistributing: rip
```

Example 16-6 *Part C: R2* **show** *and* **debug** *Output (Continued)*

```
   Default version control: send version 1, receive any version
    Interface        Send  Recv   Key-chain
    Serial0           1     1 2
    Serial1           1     1 2
    Ethernet0         1     1 2
  Automatic network summarization is in effect
  Maximum path: 4
Routing for Networks:
    163.1.0.0
  Routing Information Sources:
    Gateway         Distance      Last Update
    163.1.13.201         120      00:00:02
    163.1.23.202         120      00:00:09
  Distance: (default is 120)
```

Example 16-7 *Part C: R3* **show** *and* **debug** *Output*

```
R3#show running-config
Building configuration...

Current configuration : 888 bytes
!
version 12.2
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname R3
!
enable secret 5 $1$J3Fz$QaEYNIiI2aMu.3Ar.q0Xm.
!
ip subnet-zero
no ip domain-lookup
!
interface Serial0
 ip address 163.1.13.203 255.255.255.128
 no fair-queue
!
interface Serial1
 ip address 163.1.23.203 255.255.255.128
 encapsulation ppp
!
interface Ethernet0
 ip address 163.1.3.203 255.255.255.128

!
router rip
```

continues

Example 16-7 *Part C: R3* **show** *and* **debug** *Output (Continued)*

```
 network 163.1.0.0
!
ip classless
no ip http server
!
!
!
!
line con 0
 password cisco
 login
line aux 0
line vty 0 4
 password cisco
 login
!
end

R3#show ip arp
Protocol  Address          Age (min)  Hardware Addr   Type   Interface
Internet  163.1.3.203              -   0000.0c89.b1b0  SNAP   Ethernet0

R3#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

     163.1.0.0/16 is variably subnetted, 7 subnets, 2 masks
R       163.1.2.128/25 [120/1] via 163.1.23.202, 00:00:22, Serial1
C       163.1.3.128/25 is directly connected, Ethernet0
R       163.1.1.128/25 [120/1] via 163.1.13.201, 00:00:28, Serial0
R       163.1.12.128/25 [120/1] via 163.1.13.201, 00:00:28, Serial0
                        [120/1] via 163.1.23.202, 00:00:22, Serial1
C       163.1.13.128/25 is directly connected, Serial0
C       163.1.23.128/25 is directly connected, Serial1
C       163.1.23.202/32 is directly connected, Serial1

R3#trace 163.1.13.203


Type escape sequence to abort.
```

Example 16-7 *Part C: R3* **show** *and* **debug** *Output (Continued)*

```
Tracing the route to 163.1.13.203

  1 163.1.13.201 16 msec 16 msec 16 msec
  2 163.1.13.203 44 msec *  32 msec

R3#ping 163.1.13.203

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 163.1.13.203, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 64/66/68 ms
```

Answer the following questions. Use Examples 16-5, 16-6, and 16-7 as references:

1. What command tells you the contents of the ARP cache?
2. What command is used to find the path a packet would take from R3 to 163.1.1.1?
3. Imagine that R3's E0 interface needs to use a new IP address and mask (10.1.1.1, 255.255.255.0). If the user is in user mode, what steps are necessary to change the IP address?
4. If an exec command that you cannot recall begins with the letter *C*, how can you get Help to list all commands that start with *C*? List the steps, assuming that you are in privileged mode.
5. Name the two commands to list the currently used configuration in a router.
6. Name the two commands to list the configuration that will be used the next time the router is reloaded.
7. What does CDP stand for?

Solutions to Part C: Verification and Questions

The answers to the questions for Part C are as follows:

1. The **show ip arp** command (refer to Example 16-7) contains MAC and IP addresses.
2. The **trace 163.1.1.1** command could be used to find the path that a packet would take from R3 to 163.1.1.1 (refer to Example 16-7).
3. To change the IP address on an interface, use the following steps:

```
R3> enable
password: password
R3#configure terminal
R3(config)#interface ethernet 0
```

```
R3(config-if)#ip address 10.1.1.1 255.255.255.0
R3(config)#Ctrl-Z
R3#
```

4. To find all commands that start with the letter *C*, do the following:

```
R3#c?
clear  clock  configure  connect  copy

R3#c
```

5. The two commands that list the currently used configuration in a router are **show running-config** and **write terminal**.

6. The two commands that list the configuration that will be used the next time the router is reloaded are **show startup-config** and **show config**.

7. CDP stands for Cisco Discovery Protocol.

PART VII: Appendixes

Appendix A: Answers to the "Do I Know This Already?" Quizzes and Q&A Sections

Appendix B: Binary/Decimal Conversion Chart

Appendix C: Using the Simulation Software for Hands-on Exercises

Glossary

APPENDIX A

Answers to the "Do I Know This Already?" Quizzes and Q&A Sections

Chapter 2

"Do I Know This Already?" Quiz

1. Which of the following protocols are examples of TCP/IP transport layer protocols?

   Answer: D and F

2. Which of the following protocols are examples of TCP/IP network interface layer protocols?

   Answer: A and G

3. Which OSI layer defines the functions of logical network-wide addressing and routing?

   Answer: C

4. Which OSI layer defines the standards for cabling and connectors?

   Answer: A

5. Which OSI layer defines the standards for data formats and encryption?

   Answer: F

6. Which of the following terms are not valid terms for the names of the seven OSI layers?

   Answer: C and E

7. The process of HTTP asking TCP to send some data and make sure that it is received correctly is an example of what?

   Answer: B

8. The process of TCP on one computer marking a segment as segment 1, and the receiving computer then acknowledging the receipt of segment 1, is an example of what?

   Answer: B

9. The process of a web server adding a HTTP header to a web page, followed by adding a TCP header, then an IP header, and then data link header and trailer is an example of what?

   Answer: A

10. Which of the following terms is used specifically to identify the entity that is created when encapsulating data inside data-link headers and trailers?

    Answer: D

Q&A

1. Name the seven layers of the OSI model.

   Answer: Application (Layer 7), presentation (Layer 6), session (Layer 5), transport (Layer 4), network (Layer 3), data link (Layer 2), and physical (Layer 1). Some mnemonics to help you recall the names of the layers are: All People Seem To Need Data Processing (Layers 7 to 1), Please Do Not Take Sausage Pizzas Away (Layers 1 to 7), and the ever-popular Pew! Dead Ninja Turtles Smell Particularly Awful (Layers 1 to 7).

2. What is the main purpose(s) of Layer 7?

   Answer: Layer 7 (the application layer) provides standardized services to applications. The definition for this layer is typically ambiguous because it varies. The key is that it does not define a user interface, but instead it is a sort of toolbox used by application developers. For example, a web browser is an application that uses HTTP, as defined as a TCP/IP application layer protocol, to transfer the contents of web page between a server and client.

3. What is the main purpose(s) of Layer 6?

   Answer: Layer 6 (the presentation layer) defines data formats, compression, and possibly encryption.

4. What is the main purpose(s) of Layer 5?

   Answer: Layer 5 (the session layer) controls the conversation between two endpoints. Although the term used is session, the term conversation more accurately describes what is accomplished. The session layer ensures that not only communication, but also useful sets of communication between endpoints is accomplished.

5. What is the main purpose(s) of Layer 4?

   Answer: Layer 4 (the transport layer) provides end-to-end error recovery, if requested.

6. What is the main purpose(s) of Layer 3?

   Answer: Layer 3 (the network layer) defines logical addressing and routing as a means of delivering data across an entire network. IP and IPX are two examples of Layer 3–equivalent protocols.

7. What is the main purpose(s) of Layer 2?

   Answer: The data link layer defines addressing specific to a particular medium as part of the means of providing delivery of data across that medium. It also includes the protocols used to determine what device(s) accesses the media at any point in time.

8. What is the main purpose(s) of Layer 1?

   Answer: Layer 1 (physical layer) is responsible for encoding energy signals onto the medium and interpreting a received energy signal. Layer 1 also defines the connector and cabling details.

9. Describe the process of data encapsulation as data is processed from creation until it exits a physical interface to a network. Use the OSI model as an example.

   Answer: Data encapsulation represents the process of a layer adding a header (and possibly a trailer) to the data as it is processed by progressively lower layers in the protocol specification. In the context of OSI, each layer could add a header so that—other than the true application data—there would be six other headers (Layers 2 to 7) and a trailer for Layer 2, with this L2PDU being encoded by the physical layer onto the network media.

10. Name three benefits to layering networking protocol specifications.

    Answer: Some examples of benefits to layering networking protocol specifications include reduced complexity, standardized interfaces, modular engineering, interoperable technology, accelerated evolution, and simplified teaching and learning. Questions such as this on the exam require some subjective interpretation of the wording on your part.

11. What header or trailer does a router discard as a side effect of routing?

    Answer: A router discards the data-link header and trailer as a side effect of routing. This is because the network layer, where routing is defined, is interested in delivering the network layer (Layer 3) PDU from end to end. Routing uses intermediate data links

(Layer 2) to transport the data to the next routers and eventually to the true destination. The data-link header and trailer are useful only to deliver the data to the next router or host, so the header and trailer are discarded by each router.

12. What OSI layer typically encapsulates using both a header and a trailer?

    Answer: The data link layer typically encapsulates using both a header and a trailer. The trailer typically includes a frame check sequence (FCS), which is used to perform error detection.

13. What terms are used to describe the contents of the data encapsulated by the data link, network, and transport layers, respectively?

    Answer: Frame, packet, and segment, respectively.

14. Explain the meaning of the term L5PDU.

    Answer: PDU stands for protocol data unit. A PDU is the entity that includes the headers and trailers created by a particular networking layer, plus any encapsulated data. For instance, an L5PDU includes Layer 5 headers and the encapsulated data.

15. Explain how Layer x on one computer communicates with Layer x on another computer.

    Answer: Each layer of a networking model works with the same layer on another computer with which it wants to communicate. The protocol defined by each layer uses a header that is transmitted between the computers to communicate what each computer wants to do.

16. List the terms behind the acronym TCP/IP.

    Answer: Transmission Control Protocol and Internet Protocol.

17. List the terms behind the acronym OSI.

    Answer: Open Systems Interconnection.

Chapter 3

"Do I Know This Already?" Quiz

1. Which of the following best describes the main function of OSI Layer 1 protocols?

   Answer: B

2. Which of the following are part of the functions of OSI Layer 2 protocols?

   Answer: A

3. Which of the following is true about Ethernet crossover cables?

   Answer: B

4. Which of the following are true about the format of Ethernet addresses?

   Answer: B, C, and E

5. Which of the following is true about the Ethernet FCS field?

   Answer: C

6. Which of the following fields can be used by Ethernet as a "type" field, to define the type of data held in the "data" portion of the Ethernet frame?

   Answer: C and D

7. Which of the following are true about the CSMA/CD algorithm?

   Answer: B

8. Which of the following would be a collision domain?

   Answer: A

9. Which terms describe Ethernet addresses that can be used to communicate with more than one device at a time?

   Answer: C and D

10. With autonegotiation on a 10/100 card, what characteristics are negotiated if the device on the other end does not perform negotiation at all?

    Answer: C

Q&A

1. What is the main purpose(s) of Layer 2?

   Answer: The data link layer defines addressing specific to a particular medium as part of the means of providing delivery of data across that medium. It also includes the protocols used to determine what device(s) accesses the media at any point in time.

2. What is the main purpose(s) of Layer 1?

   Answer: Layer 1 (the physical layer) is responsible for encoding energy signals onto the medium and interpreting a received energy signal. Layer 1 also defines the connector and cabling details.

3. What does MAC stand for?

   Answer: MAC stands for Media Access Control.

4. Name three terms popularly used as a synonym for *MAC address*.

   Answer: NIC address, card address, LAN address, hardware address, Ethernet address, Token Ring address, FDDI address, and burned-in address are all synonymous with MAC address. All of these names are used casually and in formal documents, and they refer to the same 6-byte MAC address concept as defined by IEEE.

5. What portion of a MAC address encodes an identifier representing the manufacturer of the card?

   Answer: The first 3 bytes, called the Organizationally Unique Identified (OUI), comprise the portion of a MAC address that encodes an identifier representing the manufacturer of the card.

6. Are MAC addresses defined by a Layer 2 or Layer 3 protocol?

   Answer: MAC addresses are defined by a Layer 2 protocol. Ethernet and Token Ring MAC addresses are defined in the 802.3 and 802.5 specifications.

7. How many bits are present in a MAC address?

   Answer: MAC addresses have 48 bits. The first 24 bits for burned-in addresses represent a code that identifies the manufacturer.

8. Name the two main parts of a MAC address. Which part identifies which "group" this address is a member of?

   Answer: There are no parts, and nothing defines a grouping concept in a MAC address. This is a trick question. Although you might have guessed that the MAC address has two parts—the first part dictated to the manufacturer, and the second part made up by the manufacturer—there is no grouping concept.

9. What OSI layer typically encapsulates using both a header and a trailer?

   Answer: The data link layer typically encapsulates using both a header and a trailer. The trailer typically includes a frame check sequence (FCS), which is used to perform error detection.

10. If a Fast Ethernet NIC currently is receiving a frame, can it begin sending a frame?

Answer: Yes, if the NIC is operating in full-duplex mode.

11. What are the two key differences between a 10-Mbps NIC and a 10/100 NIC?

Answer: The obvious benefit is that the 10/100 NIC can run at 100 Mbps. The other benefit is that 10/100 NICs can autonegotiate both speed and duplex between itself and the device that it is cabled to, typically a LAN switch.

12. What is the distance limitation of a single cable for 10BASE-T? For 100 BASE-TX?

Answer: 10BASE-T allows 100 m between the device and the hub or switch, as does 100 BASE-TX.

13. How fast is Fast Ethernet?

Answer: 100 million bits per second (100 Mbps).

14. How many bytes long is a MAC address?

Answer: 6 bytes long, or 48 bits.

15. Define the difference between broadcast and multicast MAC addresses.

Answer: Both identify more than one device on the LAN. Broadcast always implies all devices on the LAN, whereas multicast implies some subset of all devices. Multicast is not allowed on Token Ring; broadcast is allowed on all LAN types. Devices that intend to receive frames addressed to a particular multicast address must be aware of the particular multicast address(es) that they should process. These addresses are dependent on the applications used. Read RFC 1112, "The Internet Group Message Protocol (IGMP)," for related information about the use of Ethernet multicast in conjunction with IP multicast. For example, the broadcast address is FFFF.FFFF.FFFF, and one sample multicast address is 0100.5e00.0001.

16. Explain the function of the loopback and collision-detection features of an Ethernet NIC in relation to half-duplex and full-duplex operations.

Answer: The loopback feature copies the transmitted frame back onto the receive pin on the NIC interface. The collision-detection logic compares the received frame to the transmitted frame during transmission; if the signals do not match, a collision is occurring. With full-duplex operation, collisions cannot occur, so the loopback and collision-detection features are purposefully disabled, and concurrent transmission and reception is allowed.

Chapter 4

"Do I Know This Already?" Quiz

1. Which of the following best describes the main function of OSI Layer 1 protocols?

   Answer: B

2. Which of the following typically connects to a four-wire line provided by a telco?

   Answer: B

3. Which of the following typically connects to a V.35 or RS-232 end of a cable when cabling a leased line?

   Answer: B

4. Which of the following functions of OSI Layer 2 is specified by the protocol standard for PPP, but is implemented with a Cisco proprietary header field for HDLC?

   Answer: E

5. Which of the following WAN data link protocols on Cisco routers support multiple Layer 3 protocols by virtue of having some form of Protocol Type field?

   Answer: A, B, and C

6. On a point-to-point WAN link between two routers, what device(s) are considered to be the DTE devices?

   Answer: A

7. Imagine that Router1 has three point-to-point serial links, one link each to three remote routers. Which of the following is true about the required HDLC addressing at Router1?

   Answer: E

8. What is the name of the Frame Relay field used to identify Frame Relay Virtual Circuits?

   Answer: A

9. Which of the following is true about Frame Relay virtual circuits?

   Answer: B

10. Which of the following defines a SONET link speed around 155 Mbps?

    Answer: E

Q&A

1. Are DLCI addresses defined by a Layer 2 or Layer 3 protocol?

   Answer: DLCI addresses are defined by a Layer 2 protocol. Although they are not covered specifically in this chapter, Frame Relay protocols do not define a logical addressing structure that can usefully exist outside a Frame Relay network; by definition, the addresses would be OSI Layer 2–equivalent.

2. What OSI layer typically encapsulates using both a header and a trailer?

   Answer: The data link layer typically encapsulates using both a header and a trailer. The trailer typically includes a frame check sequence (FCS), which is used to perform error detection.

3. Define the terms DCE and DTE in the context of the physical layer and a point-to-point serial link.

   Answer: At the physical layer, DTE refers to the device that looks for clocking from the device on the other end of the cable on a link. The DCE supplies that clocking. For example, the computer is typically the DTE, and the modem or CSU/DSU is the DCE. At the data link layer, both X.25 and Frame Relay define a logical DTE and DCE. In this case, the customer premises equipment (CPE), such as a router and a CSU/DSU, is the logical DTE, and the service provider equipment (the Frame Relay switch and the CSU/DSU) is the DCE.

4. Which layer or layers of OSI are most closely related to the functions of Frame Relay? Why?

   Answer: OSI Layers 1 and 2. Frame Relay refers to well-known physical layer specifications. Frame Relay does define headers for delivery across the Frame Relay cloud, making it a Layer 2 protocol. Frame Relay does not include any routing or logical addressing specifications, so it is not a Layer 3 protocol.

5. What is the name of the field that identifies, or addresses, a Frame Relay virtual circuit?

   Answer: The data-link connection identifier (DLCI) is used to identify a VC.

6. True or False: "A leased line between two routers provides a constant amount of bandwidth—never more and never less." Defend your answer.

   Answer: True. A leased line creates the cabling equivalent of having a cable between the two routers, with the speed (clock rate) defined by the telco. Even when the routers have no data to send, the full bandwidth is available to be used.

7. True or False: "Frame Relay VCs provide a constant amount of bandwidth between two devices, typically routers—never more and never less." Defend your answer.

   Answer: False. The provider assigns a guaranteed bandwidth, or CIR, for a VC, but the routers on either end of the VC can send more than the CIR of data. As long as the service provider has enough capacity to support it, the frames are forwarded over the VC.

8. Explain how many DS0 channels fit into a T1, and why the total does not add up to the purported speed of a T1, which is 1.544 Mbps.

   Answer: Each DS0 channel runs at 64 kbps. With 24 in a T1, the T1 speed seemingly would be 24 * 64 kbps, or 1.536 Mbps. T1 also includes 8 kbps for management, which, when added to the 1.536 Mbps total, gives you the full T1 rate—1.544 Mbps.

9. Define the term synchronous.

   Answer: The imposition of time ordering on a bit stream. Practically, a device will try to use the same speed as another device on the other end of a serial link. By examining transitions between voltage states on the link, the device can notice slight variations in the speed on each end and can adjust its speed accordingly.

10. Imagine a drawing with two routers, each connected to an external CSU/DSU, which each is connected with a four-wire circuit, as seen in this chapter. Describe the role of the devices in relation to clocking and synchronization.

    Answer: The routers receive clocking from their respective CSU/DSUs. One of the two CSU/DSUs is configured as the master. The other CSU/DSU, as the slave, adjusts its clock to match the speed of the master CSU/DSU.

11. Imagine a drawing with two routers, each connected to an external CSU/DSU, which each is connected with a four-wire circuit, as seen in this chapter. List the words behind the acronyms DTE and DCE, and describe which devices in this imagined network are DTE and which are DCE.

    Answer: DTE stands for data terminal equipment, and DCE stands for data communications equipment. The routers are DTEs, and the CSU/DSUs are DCEs.

12. Imagine a drawing with two routers, each connected to a Frame Relay switch over a local access link. Describe which devices in this imagined network are Frame Relay DTEs and which are Frame Relay DCEs.

    Answer: The routers are DTEs, and the Frame Relay switches are DCEs.

13. Do HDLC and PPP, as implemented by Cisco routers, support protocol type fields and error detection? Explain your answer.

    Answer: Both protocols support a protocol type field and an FCS field to perform error detection. PPP has both fields based on the protocol specification; Cisco added the protocol type field to the standard HDLC header.

14. Imagine a point-to-point leased line between two routers, with PPP in use. What are the names of the protocols inside PPP that would be used on this link? What are their main functions?

    Answer: The PPP Link Control Protocol (LCP) controls and manages the link. The IP Control Protocol (IPCP) also would be used because you need a CP for each Layer 3 protocol. IPCP can assign IP addresses to devices on the other end of a link.

15. What are some of the main similarities between Frame Relay and ATM?

    Answer: Both use an access link to access the service provider. Both use the concept of a virtual circuit between DTE devices. And both allow multiple VCs to cross a single access link.

16. Compare and contrast ATM and SONET in terms of the OSI model.

    Answer: SONET defines the Layer 1 details of passing traffic over optical cabling, whereas ATM provides the Layer 2 functionality, including link-specific addressing, framing, and error detection.

17. Besides HDLC and PPP, list the other four serial point-to-point data-link protocols covered in this chapter.

    Answer: SDLC, LAPB, LAPD, and LAPF.

18. List the speeds of a T1 line, E1, OC-3, and OC-12.

    Answer: 1.544 Mbps, 2.048 Mbps, 155 Mbps, and 622 Mbps.

Chapter 5

"Do I Know This Already?" Quiz

1. Which of the following describes the functions of OSI Layer 3 protocols?

   Answer: A and C

2. Imagine that PC1 needs to send some data to PC2, and PC1 and PC2 are separated by several routers. What are the largest entities that make it from PC1 to PC2?

   Answer: C and E

3. Which of the following does a router normally use when making a decision about routing TCP/IP?

   Answer: C

4. Imagine a network with two routers that are connected with a point-to-point HDLC serial link. Each router has an Ethernet, with PC1 sharing the Ethernet with Router1, and PC2 sharing an Ethernet with Router2. When PC1 sends data to PC2, which of the following is true?

   Answer: A

5. Which of the following are valid Class C IP addresses?

   Answer: B

6. What is the range for the values of the first octet for Class A IP networks?

   Answer: D

7. PC1 and PC2 are on two different Ethernets that are separated by an IP router. PC1's IP address is 10.1.1.1, and no subnetting is used. Which of the following addresses could be used for PC2?

   Answer: D and F

8. How many valid host IP addresses does each Class B network contain?

   Answer: D

9. How many valid host IP addresses does each Class C network contain?

   Answer: G

10. Which of the following protocols allows a client PC to discover the IP address of another computer, based on that other computer's name?

    Answer: C

11. Which of the following protocols allow a client PC to request assignment of an IP address as well as learn its default gateway?

    Answer: D

12. Which term is defined by the following phrase: "the type of protocol that is being forwarded when routers perform routing."

    Answer: A

Q&A

1. What are the two main functions of each OSI Layer 3–equivalent protocol?

   Answer: Path selection, which is also called routing, and logical addressing.

2. Assume that PC1 sends data to PC2, and PC2 is separated from PC1 by at least one router. Are the IP addresses of the PCs in the same IP subnet? Explain your answer.

   Answer: They must be in different subnets. IP addressing rules require that IP hosts separated by a router be in different subnets.

3. Assume that PC1 sends data to PC2, and PC2 is not separated from PC1 by at least one router. Are the IP, addresses of the PCs in the same IP subnet? Explain your answer.

   Answer: They must be in the same subnet. IP addressing rules require that IP hosts not separated by a router be in the same subnet.

4. How many bits are present in an IP address?

   Answer: IP addresses have 32 bits: a variable number in the network portion, and the rest of the 32 in the host portion. IP Version 6 uses a 128-bit address!

5. How many bits are present in an IPX address?

   Answer: IPX addresses have 80 bits: 32 bits in the network portion and 48 bits in the node portion.

6. How many bits are present in an AppleTalk address?

   Answer: AppleTalk addresses have 24 bits: 16 in the cable-range portion and 8 bits in the node portion.

7. Name the two main parts of an IPX address. Which part identifies which group this address is a member of?

   Answer: Network number and node number are the two main parts of an IPX address. Addresses with the same network number are in the same group. On LAN interfaces, the node number is made to have the same value as the LAN MAC address.

8. Name the two main parts of an IP address. Which part identifies which group this address is a member of?

   Answer: Network and host are the two main parts of an IP address. As described in Chapter 5, technically there are three portions of the IP address: network, subnet, and host. However, because most people think of the network and subnet portions as one portion, another correct answer to this question, using popular terminology, would be subnet and host. In short, without subnetting, the network part identifies the group; with subnetting, the network and subnet part together identifies the group.

9. PC1 sends data to PC2 using TCP/IP. Three routers separate PC1 and PC2. Explain why the statement "PC1 sends an Ethernet frame to PC2" is true or false.

   Answer: False. Packets are delivered from end to end across a network, whereas frames simply pass between devices on each common physical network. The intervening routers discard the original Ethernet header, replacing it with other data-link headers as needed. A truer statement would be "PC1 sends an IP packet to PC2."

10. In IP addressing, how many octets are in 1 byte?

    Answer: One. Octet is a generic word to describe a single byte. Each IP address is 4 bytes, or four octets, long.

11. Describe the differences between a routed protocol and a routing protocol.

    Answer: The routed protocol defines the addressing and Layer 3 header in the packet that actually is forwarded by a router. The routing protocol defines the process of routers exchanging topology data so that the routers know how to forward the data. A router uses the routing table created by the routing protocol when choosing where to route a packet.

12. Name at least three routed protocols.

    Answer: TCP/IP (IP), Novell (IPX), OSI (CLNP), DECnet (CLNP), AppleTalk (DDP), and VINES are some examples of routed protocols.

13. Name at least three IP routing protocols.

    Answer: IP RIP, IP IGRP, IP/IPX/AppleTalk EIGRP, IP OSPF, OSI NLSP, and OSI IS-IS are some examples of routing protocols.

14. Imagine an IP host on an Ethernet, with a single router attached to the same segment. In which cases does an IP host choose to send a packet to this router instead of directly to the destination host, and how does this IP host know about that single router?

Answer: Typically an IP host knows to what router to send a packet based on its configured default router. If the destination of the packet is in another subnet, the host sends the packet to the default router. Otherwise, the host sends the packet directly to the destination host because it is in the same subnet and, by definition, must be on the same data link.

15. Name three items in an entry in any routing table.

Answer: A number that identifies a group of addresses, the interface out which to forward the packet, and the Layer 3 address of the next router to send this packet to are three items that you will always find in a routing table entry. For instance, IP routes contain subnet numbers, the outgoing interface, and the IP address of the next-hop router.

16. Name the parts of an IP address when subnetting is used.

Answer: Network, subnet, and host are the three parts of an IP address. However, many people commonly treat the network and subnet parts of an address as a single part, leaving only two parts, the subnet and host parts. On the exam, the multiple-choice format should provide extra clues as to which terminology is used.

17. How many valid IP addresses exist in a Class A network? (You may refer to the formula if you do not know the exact number.)

Answer: 16,777,214, derived by the formula $2^{24} - 2$.

18. How many valid IP addresses exist in a Class B network? (You may refer to the formula if you do not know the exact number.)

Answer: 65,534, derived by the formula $2^{16} - 2$.

19. How many valid IP addresses exist in a Class C network? (You may refer to the formula if you do not know the exact number.)

Answer: 254, derived by the formula $2^8 - 2$.

20. What values can a Class A network have in the first octet?

Answer: 1 through 126, inclusive.

21. What values can a Class B network have in the first octet?

Answer: 128 through 191, inclusive.

22. What values can a Class C network have in the first octet?

Answer: 192 through 223, inclusive.

23. When subnetting a Class B network, do you create the subnet field by taking bits from the network part of the address or the host part?

Answer: Host part.

24. When subnetting a Class B network, using the entire third octet for the subnet part, describe the number of possible subnets created.

Answer: The subnet part consists of a full octet, which is 8 bits long. You can number 2^8 things with 8 bits, or 256. However, 2 subnet numbers are reserved, leaving 254 subnets.

25. When subnetting a Class A network using the entire second octet for the subnet part, describe the number of hosts in each subnet.

Answer: The host part consists of two entire octets in this case, which is 16 bits long. You can number 2^{16} things with 16 bits, or 65,536. However, 2 subnet numbers are reserved, leaving 65,534 hosts per subnet.

26. When a router hears about multiple routes to the same subnet, how does it choose which route to use?

Answer: Routing protocols use a metric to describe how good each route is. The lower the metric is, the better the route is.

27. What is the primary purpose of a routing protocol?

Answer: Routing protocols discover the routes in network and build routing tables.

28. True or false: "Routing protocols are required to learn routes of directly connected subnets."

Answer: False. Routers add routes to directly connected subnets when the interfaces initialize. No routing protocols are needed.

29. Which IP routing protocols are Cisco proprietary?

Answer: IGRP and EIGRP.

30. List the similarities and differences between RARP and BOOTP.

    Answer: Both protocols send broadcasts looking for a server, and they hope to have the server assign them an IP address. BOOTP also can be used to assign other parameters, such as the subnet mask, default gateway, DNS address, and filenames for downloading an operating system.

31. List the similarities and differences between DHCP and BOOTP.

    Answer: Both protocols send broadcasts looking for a server, and they hope to have the server assign them an IP address. Both can be used to assign a large variety of parameters, such as the subnet mask, default gateway, DNS address, and filenames for downloading an operating system. DHCP does not require that the server be preconfigured with the MAC addresses of all the DHCP client PCs, making it much more scalable.

32. List the similarities and differences between ARP and DNS.

    Answer: Both protocols send messages with one bit of information, hoping to learn another bit of information. The similarities do not go beyond that fact. DNS requests are unicast IP packets sent specifically to the DNS server, whereas ARP uses a LAN broadcast frame. DNS queries supply a name, expecting to hear the corresponding IP address back from the server. ARP requests supply an IP address, hoping to hear a corresponding MAC address not from a server, but from the host that uses that IP address.

Chapter 6

"Do I Know This Already?" Quiz

1. Which of the following protocols are connection-oriented?

   Answer: A and B

2. Which of the following protocols are reliable?

   Answer: B

3. PC1 is using TCP, has a window of 4, and sends four segments numbered 2, 3, 4, and 5 to PC2. PC2 replies with an acknowledgment number 5. What should PC1 do next?

   Answer: D

4. Which of the following are not features of a protocol that is considered to match OSI Layer 4?

   Answer: D

5. Which of the following flow-control methods let the receiver tell the sender how much data the sender is allowed to send before the sender must wait for an acknowledgment?

   Answer: C

6. Which of the following header fields identifies which TCP/IP application gets data received by the computer?

   Answer: E and F

7. Which of the TCP connection-establishment flows sets both the SYN and ACK flags in the TCP header?

   Answer: B

8. Which of the following is not a typical function of TCP?

   Answer: D and E

9. Which of the following functions is performed by TCP and UDP?

   Answer: C

10. Data that includes the Layer 4 protocol header, and data given to Layer 4 by the upper layers, not including any headers and trailers from Layers 1 to 3, is called what?

    Answer: C and G

Q&A

1. Describe the features required for a protocol to be considered connectionless.

   Answer: Unordered low-overhead delivery of data from one host to another is the service provided in most connectionless protocol services.

2. Name at least three connectionless protocols.

   Answer: LLC Type 1, UDP, IPX, and IP are some examples of connectionless protocols. Remember, Frame Relay, X.25, and ATM are connection oriented, regardless of whether they define error recovery.

3. Describe the features required for a protocol to be considered connection oriented.

   Answer: Either the protocol must exchange messages with another device before data is allowed to be sent, or some pre-established correlation between the two endpoints must be defined. TCP is an example of a connection-oriented protocol that exchanges messages before data can be sent; Frame Relay is a connection-oriented protocol for which a pre-established correlation between endpoints is defined.

4. In a particular error-recovering protocol, the sender sends three frames, labeled 2, 3, and 4. On its next sent frame, the receiver of these frames sets an Acknowledgment field to 4. What does this typically imply?

   Answer: Frames through number 3 were received successfully. The receiver might have not received Frame 4, or Frame 4 might not have passed the FCS check.

5. Name three connection-oriented protocols.

   Answer: TCP, SPX, LLC Type 2, and X.25 are some examples of connection-oriented protocols that provide error recovery. ATM and Frame Relay are also connection oriented, but without error recovery.

6. Describe how TCP performs error recovery. What role do the routers play?

   Answer: TCP numbers the first byte in each segment with a sequence number. The receiving host uses the Acknowledgment field in segments that it sends back to acknowledge receipt of the data. If the receiver sends an acknowledgment number that is a smaller number than the sender expected, the sender believes that the intervening bytes were lost, so the sender resends them. The router plays no role unless the TCP connection ends in the router—for example, a Telnet into a router. A full explanation is provided in the section "Error Recovery (Reliability)."

7. How many TCP segments are exchanged to establish a TCP connection? How many are required to terminate a TCP connection?

   Answer: A three-way connection-establishment sequence is used, and a four-way connection-termination sequence is used.

8. Describe the purpose of the Port Number field in a TCP header. Give one example.

   Answer: The port numbers are used to help computers multiplex received data. For instance, a PC with two web browsers open can receive an IP packet. The destination TCP port number identifies which of the two browsers should receive the data.

9. List the components of a TCP socket.

   Answer: A socket consists of three things: an IP address, a transport layer protocol (TCP or UDP), and the TCP or UDP port number.

10. How many TCP segments must be sent to establish a TCP connection? How many are used with normal TCP connection termination?

    Answer: Three TCP segments are needed to establish the connection, and four are needed to tear it down under normal operation.

11. How many UDP segments must be sent to establish a UDP connection? How many are used with normal UDP connection termination?

    Answer: UDP does not establish connections because it is not connection oriented.

Chapter 7

"Do I Know This Already?" Quiz

1. In which of the following modes of the CLI could you configure a description of Ethernet0?

   Answer: E. The description command is an interface subcommand.

2. In which of the following modes of the CLI could you issue a command to reboot the router?

   Answer: B. The reload command is an exec command, so it cannot be issued from any configuration mode. User mode does not allow the use of the reload command.

3. What type of router memory is used to store the configuration used by the router when it is up and working?

   Answer: A. The IOS loads the config from NVRAM into RAM during the boot sequence; therefore, the router uses the configuration in RAM for normal operations.

4. What type of router memory is used to store the operating system used for low-level debugging and not for normal operation?

   Answer: B. The ROMMON operating system is stored in ROM.

5. What command copies the configuration from RAM into NVRAM?

   Answer: F. The first parameter identifies the source of the config, and the last parameter identifies the destination.

6. What mode prompts the user for basic configuration information?

   Answer: D

7. Which of the following could cause a router to change the IOS that is loaded when the router boots?

   Answer: D and F. The boot command is a configuration command that identifies the source and possibly the name of the IOS to load. The configuration register tells the router the source from which to find the file containing the IOS.

8. Which of the following hexadecimal values in the last nibble of the configuration register would cause a router to not look in Flash memory?

   Answer: A and B. A 0 makes the router load ROMMON code; a 1 makes the router load the RXBOOT IOS image.

9. Imagine that you have configured the **enable secret** command, followed by the **enable password** command, from the console. You log out of the router and log back in at the console. Which command defines the password that you had to type to access the router again from the console?

   Answer: C. The password subcommand, under the line console 0 command, sets the console password.

10. Imagine that you have configured the **enable secret** command, followed by the **enable password** command, from the console. You log out of the router and log back in at the console. Which command defines the password that you had to type to access privileged mode?

    Answer: B. If both are configured, the enable secret password is required to gain access to privileged mode.

Q&A

1. What are the two names for the same CLI mode in a router, that when accessed, enables you to issue exec commands that could be disruptive to router operations?

   Answer: Enable mode and privileged mode. Both names are commonly used and are found in Cisco documentation.

2. What are three methods of logging on to a router?

   Answer: Console, auxiliary port, and Telnet. All three cause the user to enter user exec mode.

3. What is the name of the user interface mode of operation used in which you cannot issue disruptive commands?

   Answer: User exec mode.

4. Can the auxiliary port be used for anything besides remote modem user access to a router? If so, what other purpose can it serve?

   Answer: Yes. For direct attachment of a terminal, and dial for the purpose of routing packets. Although it originally was created to support remote administration access, many customers use an auxiliary port for dial backup, particularly when analog lines are desired or when that is all that is available.

5. What command would you use to receive command help if you knew that a **show** command option begins with a c but you cannot recall the option?

   Answer: show c?. Help would appear immediately after you typed the ? symbol. You would not need to press Enter after the ?. If you did so, the router would try to execute the command with only the parameters that you had typed after the ?.

6. While you are logged in to a router, you issue the command **copy ?** and get a response of "Unknown command, computer name, or host." Offer an explanation for why this error message appears.

   Answer: You were in user mode. You must be in enable/privileged mode to use the copy command. When in user mode, the router does not provide help for privileged commands, and it treats the request for help as if there is no such command.

7. Is the number of retrievable commands based on the number of characters in each command, or is it simply a number of commands, regardless of their size?

   Answer: The number of commands. The length (that is, the number of characters) of each command does not affect the command history buffer.

8. How can you retrieve a previously used command? (Name two ways.)

   Answer: Ctrl-p and up arrow (literally the up arrow key on the keyboard). Not all terminal emulators support Ctrl-p or the up arrow, so recalling both methods is useful.

9. After typing **show ip route**, which is the only command that you typed since logging in to the router, you now want to issue the **show ip arp** command. What steps would you take to execute this command by using command-recall keystrokes?

   Answer: Press the up arrow, press Backspace five times, and type arp. The up arrow key retrieves the show ip route command. Backspace moves the cursor backward and erases the character. Typing inserts the characters into the line.

10. After typing **show ip route 128.1.1.0**, you now want to issue the command **show ip route 128.1.4.0**. What steps would you take to do so, using command-recall and command-editing keystrokes?

Answer: Press the up arrow or Ctrl-p, then press Ctrl-b (or the left arrow) twice, and press Backspace once; and type 4. The Ctrl-b and left arrow keys back up one character in the line, without deleting the character. The Backspace key deletes the 1, in this case. And newly typed characters appear where the cursor sits in the command line.

11. What configuration command causes the router to require a password from a user at the console? What configuration mode context must you be in? (That is, what command[s] must be typed before this command after entering configuration mode?) List the commands in the order in which they must be typed while in config mode.

```
line console 0
login
```

Answer: The line console 0 command is a context-setting command; it adds no information to the configuration. The command can be typed from any part of configuration mode. The login command, which follows the line console 0 command, tells IOS that a password prompt is desired at the console.

12. What configuration command is used to tell the router the password that is required at the console? What configuration mode context must you be in? (That is, what command[s] must you type before this command after entering configuration mode?) List the commands in the order in which they must be typed while in config mode.

```
line console 0
password xxxxxxx
```

Answer: The password command tells IOS the value that should be typed when a user wants access from the console. This value is requested by IOS because of the login command. The password *xxxxxxx* must be typed while in console configuration mode, which is reached by typing line console 0.

13. What are the primary purposes of Flash memory in a Cisco router?

Answer: To store IOS and microcode files. In most routers, only IOS is stored in flash. If microcode is upgraded, the files also reside in Flash memory.

14. What is the intended purpose of NVRAM memory in a Cisco router?

Answer: To store a single configuration file, used at router load time. NVRAM does not support multiple files.

15. What does the NV stand for in NVRAM?

Answer: Nonvolatile. NVRAM is battery powered if it is really RAM. In some routers, Cisco has (sneakily) used a small portion of Flash memory for the purpose of NVRAM, but Cisco would not ask such trivia on the test.

16. What is the intended purpose of RAM in a Cisco router?

Answer: RAM is used as IOS working memory (storing such things as routing tables or packets) and for IOS code storage. (In some router models, not all IOS is copied into RAM. Some of IOS is left in Flash memory so that more RAM is available for working memory.) It also holds the currently-in-use configuration file called running-config.

17. What is the main purpose of ROM in a Cisco router?

Answer: To store a small, limited-function version of IOS and to store bootstrap code. Typically, this type of IOS is used only during maintenance or emergencies.

18. What configuration command would be needed to cause a router to use an IOS image named c2500-j-l.112-14.bin on TFTP server 128.1.1.1 when the router is reloaded? If you forgot the first parameter of this command, what steps must you take to learn the correct parameters and add the command to the configuration? (Assume that you are not logged in to the router when you start.)

```
boot system tftp c2500-j-l.112-14.bin 128.1.1.1
```

Answer: As for the second part of the question: Log in from con/aux/telnet, type the enable command, type the enable password, type the configure terminal command, and type boot ?. Help appears for the first parameter of the boot command.

19. What command sets the password that would be required after typing the **enable** command? Is that password encrypted by default?

Answer: enable password or enable secret. The password in the enable command is not encrypted, by default. The enable secret password is encrypted using MD5.

20. To have the correct syntax, what must you add to the following configuration command?

```
banner This is Ivan Denisovich's Gorno Router--Do Not Use
```

Answer: This command does not use a delimiter character at the beginning and end of the text. The correct syntax follows:

```
banner # This is Ivan.... Do Not Use #
```

Answer: As typed, IOS would think that the letter T was the delimiter character, so the banner actually would be "his is Ivan Denisovich's Gorno Rou". The motd parameter is not shown because it is not required. An alternate correct command would be this:

```
banner motd # This is Ivan.... Do Not Use #
```

21. Name two commands that affect the text used as the command prompt.

Answer: hostname and prompt.

22. When using setup mode, you are prompted at the end of the process for whether you want to use the configuration parameters that you just typed in. Which type of memory is this configuration stored in if you type yes?

Answer: Both NVRAM and RAM. Setup is the only IOS feature that modifies both the active and the startup configuration files as the result of one action by the user.

23. What two methods could a router administrator use to cause a router to load IOS stored in ROM?

Answer: Setting the configuration register boot field to binary 0001, or adding boot system rom to the configuration file and copying it to the startup configuration file. To set the configuration register to hex 2101, which would yield binary 0001 in the boot field, the config-register 0x2101 global configuration command would be used. A third method, not mentioned in the chapter, includes removing the Flash memory in a router and then reloading.

24. What is the process used to update the contents of Flash memory so that a new IOS in a file called c4500-d-mz.120-5.bin on TFTP server 128.1.1.1 is copied into Flash memory?

Answer: copy tftp flash. The other details—namely, the IP address of the TFTP server and the filename—are requested through prompts to the user.

25. Name three possible problems that could prevent the command **boot system tftp c2500-j-l.112-14.bin 128.1.1.1** from succeeding.

Answer: The possible reasons include: 128.1.1.1 is not accessible through the network, there is no TFTP server on 128.1.1.1, the file is not in the TFTP default directory, the file is corrupted, a different boot command could precede this boot command in the configuration file, meaning that the IOS referenced in the first boot command would be used instead.

26. Two different IOS files are in a router's Flash memory: one called c2500-j-l.111-3.bin and one called c2500-j-l.112-14.bin. Which one does the router use when it boots up? How could you force the other IOS file to be used? Without looking at the router configuration, what command could be used to discover which file was used for the latest boot of the router?

Answer: The first IOS file listed in the show flash command is the one used at reload time, unless a boot system command is configured. The configuration command boot system flash c2500-j-l.112-14.bin would override the IOS's decision to look for files in order in Flash memory. show version is the command used to display the filename of IOS

for the latest reload of a router. The show version output tells you the version as well as the name of the file that was used at last reload time. It is particularly difficult to find in the output of the command.

27. Is the password required at the console the same one that is required when Telnet is used to access a router?

Answer: No. The Telnet (virtual terminal) password is not the same password, although many installations use the same value.

28. Which IP routing protocols could be enabled using setup?

Answer: RIP and IGRP.

29. Name two commands used to view the configuration to be used at the next reload of the router. Which one is a more recent addition to IOS?

Answer: show config and show startup-config. show startup-config is the newer one and, hopefully, is easier to remember.

30. Name two commands used to view the configuration that currently is used in a router. Which one is a more recent addition to IOS?

Answer: write terminal and show running-config. show running-config is the newer command and, hopefully, is easier to remember.

31. True or false: The **copy startup-config running-config** command always changes the currently used configuration for this router to exactly match what is in the startup configuration file. Explain.

Answer: False. Some configuration commands do not replace an existing command but simply are added to a list of related commands. If such a list exists, the copy startup-config running-config command simply adds those to the end of the list. Many of these lists in a router configuration are order dependent.

Chapter 8

"Do I Know This Already?" Quiz

1. In which of the following modes of the CLI could you configure the duplex setting for interface fastethernet 0/5?

Answer: E. The duplex command is an interface subcommand.

2. In which of the following modes of the CLI could you issue a command to erase the initial configuration of the switch?

   Answer: B. The erase command is an exec command, so it cannot be issued from any configuration mode. User mode does not allow the use of the erase command.

3. What type of switch memory is used to store the configuration used by the switch when the switch first comes up?

   Answer: D. IOS loads the config from NVRAM into RAM during the boot sequence.

4. What command copies the configuration from RAM into NVRAM?

   Answer: F. The first parameter identifies the source of the config, and the last parameter identifies the destination.

5. What mode prompts the user for basic configuration information?

   Answer: D

6. Imagine that you had configured the **enable secret** command, followed by the **enable password** command, from the console. You log out of the switch and log back in at the console. Which command defined the password that you had to type to access privileged mode again from the console?

   Answer: B. When both are configured, the enable secret password takes precedence over the enable password.

7. In what LED mode does the switch use the per-port LEDs to show information about the current load on the switch?

   Answer: B

8. Which of the following is not true of both a 2950 switch and Cisco routers?

   Answer: A. 2950 switches do not have auxiliary ports.

Q&A

1. What are the two names for the switch's mode of operation that, when accessed, enables you to issue commands that could be disruptive to switch operations?

   Answer: Enable mode and privileged mode. Both names are commonly used and found in Cisco documentation.

2. What are two methods of logging on to a switch?

   Answer: Console and Telnet. Both cause the user to enter user exec mode.

3. What is the name of the user interface mode of operation used when you cannot issue disruptive commands?

   Answer: User exec mode.

4. What command would you use to receive command help if you knew that a **show** command option begins with a *c* but you cannot recall the option?

   Answer: show c?. Help would appear immediately after you typed the ? symbol. You would not need to press Enter after the ?. If you did so, the switch would try to execute the command with only the parameters that you had typed after the ?.

5. While you are logged in to a switch, you issue the command **copy ?** and get a response of "Unknown command, computer name, or host." Offer an explanation for why this error message appears.

   Answer: You were in user mode. You must be in enable/privileged mode to use the copy command. When in user mode, the switch does not provide help for privileged commands, and it treats the request for help as if there is no such command.

6. How can you retrieve a previously used command? (Name two ways.)

   Answer: Use Ctrl-p and the up arrow (literally the up arrow key on the keyboard). Not all terminal emulators support Ctrl-p or the up arrow, so recalling both methods is useful.

7. What configuration command causes the switch to require a password from a user at the console? What configuration mode context must you be in? (That is, what command[s] must be typed before this command after entering configuration mode?) List the commands in the order in which they must be typed while in config mode.

   ```
   line console 0
   login
   ```

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line console 0
password xxxxxxx
```

Answer: The password command tells IOS the value that should be typed when a user wants access from the console. This value is requested by IOS because of the login command. The password xxxxxxx must be typed while in console configuration mode, which is reached by typing line console 0.

9. What are the primary purposes of Flash memory in a Cisco switch?

Answer: To store IOS and microcode files. In most switches, only IOS is stored in flash. If microcode is upgraded, the files also reside in Flash memory.

10. What is the intended purpose of NVRAM memory in a Cisco 2950 switch?

Answer: To store a single configuration file, used at switch load time. NVRAM does not support multiple files.

11. What does the "NV" stand for in NVRAM?

Answer: Nonvolatile. NVRAM is battery powered if it is really RAM. In some switches, Cisco has (sneakily) used a small portion of Flash memory for the purpose of NVRAM, but Cisco would not ask such trivia on the test.

12. What is the intended purpose of RAM in a Cisco 2950 switch?

Answer: RAM is used as IOS working memory (storing such things as MAC address tables and frames) and for IOS code storage.

13. What command sets the password that would be required after typing the **enable** command? Is that password encrypted by default?

Answer: enable password or enable secret. The password in the enable command is not encrypted, by default. The enable secret password is encrypted using MD5.

14. Is the password required at the console the same one that is required when Telnet is used to access a switch?

    Answer: No. The Telnet ("virtual terminal") password is not the same password, although many installations use the same value.

15. Name two commands used to view the configuration to be used at the next reload of a 2950 switch. Which one is a more recent addition to IOS?

    Answer: show config and show startup-config. show startup-config is the newer one and, hopefully, is easier to remember.

16. Name two commands used to view the configuration that is currently used in a 2950 switch. Which one is a more recent addition to IOS?

    Answer: write terminal and show running-config. show running-config is the newer command and, hopefully, is easier to remember.

Chapter 9

"Do I Know This Already?" Quiz

1. Which of the following statements describes part of the process of how a transparent bridge makes a decision to forward a frame destined to a unicast MAC address?

   Answer: A

2. Which of the following statements describes part of the process of how a LAN switch makes a decision to forward a frame destined to a broadcast MAC address?

   Answer: C

3. Which of the following statements best describes what a transparent bridge does with a frame destined to an unknown unicast address?

   Answer: A

4. Which of the following comparisons is made by a switch when deciding whether a new MAC address should be added to its bridging table?

   Answer: B

5. Which of the following internal switching methods can start forwarding a frame before the entire frame has been received?

   Answer: C and D

6. Which of the following internal switching methods must wait to receive the entire frame before forwarding the frame?

   Answer: E

7. Which of the following features is determined during autonegotiation between a 10/100 Ethernet card and a switch?

   Answer: A and D

8. Which of the following devices would be in the same collision domain as PC1 below?

   Answer: A

9. Which of the following devices would be in the same broadcast domain as PC1 below?

   Answer: A, B, and C

10. A network currently has ten PCs, with five connected to hub1 and another five connected to hub2, with a cable between the two hubs. Fred wants to keep the PCs connected to their hubs but put a bridge between the two hubs. Barney wants to remove the hubs and connect all ten PCs to the same switch. Comparing Fred and Barney's solutions, which of the following is true?

    Answer: A, B, and D

11. Imagine a network with three switches, each with an Ethernet segment connecting it to the other two switches. Each switch has some PCs attached to it as well. Which of the following frames would cause loops if the Spanning Tree Protocol were not running?

    Answer: A and C. Without STP, any frame that a switch would forward out all ports would loop for an indefinitely long period of time. Switches always forward broadcasts out all ports. Likewise, unicast frames to MAC addresses that are not in the MAC address table are flooded out all ports.

12. Which of the following interface states could a switch interface settle into after STP has completed building a spanning tree?

    Answer: B and C

Q&A

1. Name two of the methods of internal switching on typical switches today. Which provides less latency for an individual frame?

   Answer: Store-and-forward, cut-through, and Fragment Free switching. Cut-through switching has less latency per frame but does not check for bit errors in the frame, including errors caused by collisions. Store-and-forward switching stores the entire received frame, verifies that the FCS is correct, and then sends the frame. Cut-through switching sends out the first bytes of the frame before the last bytes of the incoming frame have been received. Fragment Free switching is similar to cut-through switching in that the frame can be sent before the incoming frame is totally received; however, Fragment Free processing waits to receive the first 64 bytes, to ensure no collisions, before beginning to forward the frame.

2. Describe how a transparent bridge decides whether it should forward a frame, and tell how it chooses the output interface.

   Answer: The bridge examines the destination MAC address of a frame and looks for the address in its bridge (or address) table. If found, the matching entry tells the bridge which output interface to use to forward the frame. If not found, the bridge forwards the frame out all other interfaces (except for interfaces blocked by spanning tree and the interface in which the frame was received). The bridge table is built by examining incoming frames' source MAC addresses.

3. Define the term collision domain.

   Answer: A collision domain is a set of Ethernet devices for which concurrent transmission of a frame by any two of them will result in a collision. Bridges, switches, and routers separate LAN segments into different collision domains. Repeaters and shared hubs do not separate segments into different collision domains.

4. Name two benefits of LAN segmentation using transparent bridges.

   Answer: The main benefits are reduced collisions and more cumulative bandwidth. Multiple 10- or 100- Mbps Ethernet segments are created, and unicasts between devices on the same segment are not forwarded by the bridge, which reduces overhead. Because frames can be sent over each segment at the same time, it increases the overall bandwidth available in the network.

5. What routing protocol does a transparent bridge use to learn about Layer 3 addressing groupings?

   Answer: None. Bridges do not use routing protocols. Transparent bridges do not care about Layer 3 address groupings. Devices on either side of a transparent bridge are in the same Layer 3 group—in other words, the same IP subnet or IPX network.

6. If a Fast Ethernet NIC currently is receiving a frame, can it begin sending a frame?

   Answer: Yes, if the NIC is operating in full-duplex mode.

7. Why did Ethernet networks' performance improve with the advent of bridges?

   Answer: Before bridges and switches existed, all devices were cabled to the same shared Ethernet. The CSMA/CD algorithm was used to determine who got to send across the Ethernet. As the amount of traffic increased, collisions and waiting (because CSMA/CD) increased, so frames took longer to send. Bridges separated the network into multiple collision domains, reducing collisions and allowing devices on opposite sides of the bridge to send concurrently.

8. Why did Ethernet networks' performance improve with the advent of switches?

   Answer: Before bridges and switches existed, all devices were cabled to the same shared Ethernet. The CSMA/CD algorithm was used to determine who got to send across the Ethernet. As the amount of traffic increased, collisions and waiting (because of CSMA/CD) increased, so frames took longer to send. Switches separated the network into multiple collision domains, typically one per port, reducing collisions and allowing devices on opposite sides of the bridge to send concurrently.

9. What are two key differences between a 10-Mbps NIC and a 10/100 NIC?

   Answer: The obvious benefit is that the 10/100 NIC can run at 100 Mbps. The other benefit is that 10/100 NICs can autonegotiate both speed and duplex between themselves and the device that they are cabled to—typically a LAN switch.

10. Assume that a building has 100 devices attached to the same Ethernet. These users then are migrated onto two separate shared Ethernet segments, each with 50 devices, with a transparent bridge between them. List two benefits that would be derived for a typical user.

    Answer: Fewer collisions due to having two collision domains. Also, less waiting should occur because twice as much capacity exists.

11. Assume that a building has 100 devices attached to the same Ethernet. These devices are migrated to two different shared Ethernet segments, each with 50 devices. The two segments are connected to a Cisco LAN switch to allow communication between the two sets of users. List two benefits that would be derived for a typical user.

    Answer: Two switch ports are used, which reduces the possibility of collisions. Also, each segment has its own 10- or 100-Mbps capacity, allowing more throughput and reducing the likelihood of collisions. Furthermore, some Cisco switches can reduce the flow of multicasts using the Cisco Group Message Protocol (CGMP) and IGMP snooping.

12. How fast is Fast Ethernet?

Answer: 100 million bits per second (100 Mbps).

13. How does a transparent bridge build its address table?

Answer: The bridge listens for incoming frames and examines the source MAC address. If it is not in the table, the source address is added, along with the port (interface) by which the frame entered the bridge. The bridge also marks an entry for freshness so that entries can be removed after a period of disuse. This reduces table size and allows for easier table changes in case a spanning tree change forces more significant changes in the bridge (address) table.

14. How many bytes long is a MAC address?

Answer: 6 bytes long, or 48 bits.

15. Does a bridge or switch examine just the incoming frame's source MAC, the destination MAC, or both? Why does it examine the one(s) that it examines?

Answer: The bridge or switch examines both MAC addresses. The source is examined so that entries can be added to the bridge/address table. The destination address is examined to determine the interface out which to forward the frame. Table lookup is required for both addresses for any frame that enters an interface. That is one of the reasons that LAN switches, which have a much larger number of interfaces than traditional bridges, need to have optimized hardware and logic to perform table lookup quickly.

16. Define the term broadcast domain.

Answer: A broadcast domain is a set of Ethernet devices for which a broadcast sent by any one of them should be received by all others in the group. Unlike routers, bridges and switches do not stop the flow of broadcasts. Two segments separated by a router each would be in different broadcast domains. A switch can create multiple broadcast domains by creating multiple VLANs, but a router must be used to route packets between the VLANs.

17. Describe the benefits of creating 3 VLANs of 25 ports each, versus a single VLAN of 75 ports, in each case using a single switch. Assume that all ports are switched ports (each port is a different collision domain).

Answer: Three different broadcast domains are created with three VLANs, so the devices' CPU utilization should decrease because of decreased broadcast traffic. Traffic between devices in different VLANs will pass through some routing function, which can add some latency for those packets. Better management and control are gained by including a router in the path for those packets.

18. Explain the function of the loopback and collision-detection features of an Ethernet NIC in relation to half-duplex and full-duplex operations.

Answer: The loopback feature copies the transmitted frame back onto the receive pin on the NIC interface. The collision-detection logic compares the received frame to the transmitted frame during transmission; if the signals do not match, a collision is occurring. With full-duplex operation, collisions cannot occur, so the loopback and collision-detection features are purposefully disabled, and concurrent transmission and reception is allowed.

19. Describe the benefit of the Spanning Tree Protocol as used by transparent bridges and switches.

Answer: Physically redundant paths in the network are allowed to exist and be used when other paths fail. Also, loops in the bridged network are avoided. Loops are particularly bad because bridging uses LAN headers, which do not provide a mechanism to mark a frame so that its lifetime can be limited; in other words, the frame can loop forever.

20. Name the three reasons why a port is placed in forwarding state as a result of spanning tree.

Answer: First, all ports on the root bridge are placed in forwarding state. Second, one port on each bridge is considered its root port, which is placed in forwarding state. Finally, on each LAN segment, one bridge is considered to be the designated bridge on that LAN; that designated bridge's interface on the LAN is placed in a forwarding state.

21. Name the three interface states that the Spanning Tree Protocol uses other than forwarding. Which of these states is transitory?

    Answer: Blocking, Layer 2 listening, and learning. Blocking is the only stable state; the other two are transitory between blocking and forwarding.

Chapter 10

"Do I Know This Already?" Quiz

1. 1.In a LAN, which of the following terms best equates to the term VLAN?

   Answer: B. By definition, a VLAN includes all devices in the same LAN broadcast domain.

2. Imagine a switch with three configured VLANs. How many IP subnets would be required, assuming that all hosts in all VLANs want to use TCP/IP?

   Answer: D. The hosts in each VLAN must be in different subnets.

3. Which of the following fully encapsulates the original Ethernet frame in a trunking header?

   Answer: B. ISL fully encapsulates the original frame, whereas 802.1q simply adds an additional header inside the original Ethernet frame.

4. Which of the following allows a spanning tree instance per VLAN?

   Answer: D

5. Imagine a Layer 2 switch with three configured VLANs, using an external router for inter-VLAN traffic. What is the least number of router Fast Ethernet interfaces required to forward traffic between VLANs?

   Answer: B. You can use one Fast Ethernet interface and use trunking between the router and the switch. A router is required to forward traffic between the VLANs.

6. Which of the following terms refers to a function that can forward traffic between two different VLANs?

   Answer: B and C. Layer 2 switching forwards frames only inside a single VLAN. Layer 3 switching and Layer 4 switching forward traffic between VLANs, either based on the Layer 3 destination address (Layer 3 switching) or the Layer 4 port numbers (Layer 4 switching).

7. Imagine a small campus network with three VLANs spread across two switches. Which of the following would you expect to also have a quantity of 3?

   Answer: B and C. By definition, a VLAN is a set of devices in the same broadcast domain. An IP subnet on a LAN is typically comprised of devices in the same VLAN.

8. Which of the following are considered to be ways of configuring VLANs?

   Answer: A and B.

Q&A

1. Define the term collision domain.

   Answer: A collision domain is a set of Ethernet devices for which concurrent transmission of a frame by any two of them will result in a collision. Bridges, switches, and routers separate LAN segments into different collision domains. Repeaters and shared hubs do not separate segments into different collision domains.

2. Define the term broadcast domain.

   Answer: A broadcast domain is a set of Ethernet devices for which a broadcast sent by any one of them should be received by all others in the group. Unlike routers, bridges and switches do not stop the flow of broadcasts. Two segments separated by a router would each be in a different broadcast domain. A switch can create multiple broadcast domains by creating multiple VLANs, but a router must be used to route packets between the VLANs.

3. Define the term VLAN.

   Answer: Virtual LAN (VLAN) refers to the process of treating one subset of a switch's interfaces as one broadcast domain. Broadcasts from one VLAN are not forwarded to other VLANs; unicasts between VLANs must use a router. Advanced methods, such as Layer 3 switching, can be used to allow the LAN switch to forward traffic between VLANs without each individual frame being routed by a router.

4. If two Cisco LAN switches are connected using Fast Ethernet, what VLAN trunking protocols could be used? If only one VLAN spanned both switches, is a VLAN trunking protocol needed?

   Answer: ISL and 802.1q are the trunking protocols used by Cisco over Fast Ethernet. If only one VLAN spans the two switches, a trunking protocol is not needed. Trunking or tagging protocols are used to tag a frame as being in a particular VLAN; if only one VLAN is used, tagging is unnecessary.

5. Must all members of the same VLAN be in the same collision domain, the same broadcast domain, or both?

   Answer: By definition, members of the same VLAN are all part of the same broadcast domain. They might all be in the same collision domain, but only if all devices in the VLAN are connected to hubs.

6. What is the acronym and complete name of Cisco's proprietary trunking protocol over Ethernet?

   Answer: Inter-Switch Link (ISL).

7. Consider the phrase "A VLAN is a broadcast domain is an IP subnet." Do you agree or disagree? State your reasons.

   Answer: From one perspective, the statement is false because an IP subnet is a Layer 3 protocol concept, and a broadcast domain and VLAN are Layer 2 concepts. However, the devices in one broadcast domain comprise the exact same set of devices that would be in the same VLAN and in the same IP subnet.

8. What fields are added or changed in an Ethernet header when using 802.1q? Where is the VLAN ID in those fields?

   Answer: A new 4-byte 802.1q header, which includes the VLAN ID, is added after the source MAC address field. The original FCS field in the Ethernet trailer is modified because the value must be recalculated as a result of changing the header.

9. Compare and contrast the use of a Layer 3 switch versus an external router connected to a Layer 2 switch using a trunk for forwarding between VLANs.

   Answer: Functionally, the end result of each process is identical. However, L3 switches optimize the internal processing of the switch, using a very fast forwarding path, typically using ASICs. The end result is that L3 switches forward traffic between VLANs at much higher speeds than do externally attached routers.

10. Compare and contrast a Layer 3 switch with a multilayer switch. Describe in what cases the terms could be used synonymously.

    Answer: A Layer 3 switch forwards packets based on their destination IP address, much like a router, but with the forwarding logic performed quickly inside hardware in the switch. A multilayer switch performs switching at multiple layers. Many Layer 3 switches also perform Layer 2 switching for frames destined to another device in the same VLAN, and Layer 3 switching for packets destined to another subnet/VLAN. The terms are often used synonymously because many people assume that a LAN switch can always perform L2 switching, with L3 switching being an additional function.

Chapter 11

"Do I Know This Already?" Quiz

1. Which of the following network topologies is characterized by attachments from many devices to a single linear cable?

   Answer: A

2. Which of the following types of networks is considered to be a logical bus topology?

   Answer: A and B. 10BASE5 is a physical bus, and it behaves like a bus, making it a logical bus topology. Because a 10BASE-T hub repeats incoming transmissions out all other ports, effectively creating a bus, it is considered to be a logical bus topology.

3. Which pins typically are used on an RJ-45 connector by an Ethernet card to support Fast Ethernet over UTP cabling?

   Answer: C

4. Which part of an optical cable reflects the light back into the cable as a result of a different refractive index?

   Answer: A

5. Which of the following UTP cable types support Gigabit Ethernet?

   Answer: C, D, and E.

6. Which of the following Ethernet standards call for the use of 802.3 MAC and 802.2 LLC standards?

   Answer: E. All the Ethernet standards call for the use of 802.3 framing, including the 802.3 MAC and 802.2 LLC sublayers.

7. Which of the following Ethernet standards refer to Gigabit Ethernet?

   Answer: B and C. 802.3z refers to Gigabit over optical, and 802.3ab refers to Gigabit over copper cabling.

8. Which of the following IEEE standards define framing used when transmitting wireless LAN traffic?

   Answer: A and D. Wireless LANs use the IEEE 802.11 standard instead of 802.3 for the MAC sublayer header, and also use IEEE 802.2 for the LLC sublayer header.

Q&A

1. Describe why a 10BASE-T network using a hub is considered to be a logical bus topology.

   Answer: A physical bus causes the transmitted electrical signal to be propagated to all devices connected to the bus. A 10BASE-T hub repeats a signal entering one port out all the other ports, ensuring that all devices receive the same signal. Hubs do not have any logic to prevent some frames from being sent out ports (all signals are repeated), creating a single collision domain, just like a physical bus.

2. Compare and contrast full-mesh versus partial-mesh topologies, in relation to physical topologies.

   Answer: In a full mesh, for a particular set of networking devices, a direct cable connects each pair of devices. For a partial mesh, some pairs of devices are not directly connected.

3. Compare and contrast full-mesh versus partial-mesh topologies, in relation to logical topologies.

   Answer: Regardless of the physical topology, a topology is considered a logical full mesh if each pair of devices can communicate directly, and is considered a partial mesh if some pairs cannot communicate directly. A Frame Relay network uses a star physical topology. Depending on what VCs have been defined, it might use a logical full mesh or a logical partial mesh.

4. What is the main motivation for using a dual-ring physical topology versus a single ring? Why?

   Answer: For better network availability. With dual rings, if a cable or a device fails, the devices near the failure can loop the signals from the two different cables together, thereby creating a single phyiscal path that loops to each node.

5. What two methods are used to reduce the amount of electromagnetic emissions emanating from copper Ethernet cabling? Why do they help reduce emissions?

   Answer: By using two pairs of wires for transmission, with differing currents, and twisting the wires, the magnetic fields generated when the electrical current flows are cancelled. The other method is to put insulating material around the wires, which shields the emissions to a great degree.

6. Which wires are used by a typical Ethernet CAT5 cable? Which ones are used for transmit, and which ones are used to receive, by an Ethernet card?

   Answer: Ethernet cards transmit on the pair using pins 1 and 2, and receive on the pair at pins 3 and 6.

7. Which TIA standards for UTP cabling support 10BASE-T?

   Answer: CAT3, 5, 5e, and 6.

8. What are the maximum lengths for coaxial cables as used by 10BASE5? 10BASE2?

   Answer: 500 m and 185 m, respectively.

9. What are key differences between multimode and single-mode optical cabling?

   Answer: Multimode cabling typically supports shorter distances than single-mode. Single-mode uses a much smaller diameter for the glass fiber, which allows for the greater distances.

10. What types of cabling are least susceptible to having someone eavesdrop and somehow discover what is being transmitted over the cable?

    Answer: Optical cables do not emit any EM radiation outside the cable, as do metallic copper cables. So, you cannot simply sense what signal is crossing over an optical cable without physically breaking into the cable, which makes the cable unusable.

11. What are the IEEE standards for 10BASE-T, Fast Ethernet, Gigabit Ethernet, and 10-Gigabit Ethernet?

    Answer: 802.3, 802.3u (Fast Ethernet), 802.3z and 802.3ab (Gigabit Ethernet), and 802.3ae (10 Gigabit).

12. Which variations on the Fast Ethernet standard, which use names like "10BASE-something," specifically state the need for four pairs of wires in the cable? What about for Gigabit Ethernet?

    Answer: 100BASE-T4 for Fast Ethernet, and 1000BASE-T for Gigabit Ethernet.

13. Which variations on the Fast Ethernet and Gigabit standard use IEEE 802.3 MAC and 802.2 LLC framing?

    Answer: All of them.

14. What were some of the differences between 10-Gigabit Ethernet, as compared with other types of Ethernet, as outlined in this chapter?

    Answer: The speed, of course, is the obvious difference. Additionally, 10-Gigabit Ethernet is allowed to be used in a point-to-point topology only, it supports full-duplex only, and today it supports only optical cabling.

15. What IEEE standards are used by an 802.11 access point?

    Answer: The access point uses 802.11 standards for communication across the wireless LAN, including 802.2 LLC. It also connects to a wired LAN, so it uses 802.3 for its wired Ethernet.

16. What does the term line-of-sight mean in relation to wireless communications?

    Answer: Line-of-sight means that you could stand beside one device, and see the other device. Some wireless technologies require a line-of-sight, and others do not.

Chapter 12

"Do I Know This Already?" Quiz

1. Which of the following is the result of a Boolean AND between IP address 150.150.4.100, mask 255.255.192.0?

   Answer: B

2. If mask 255.255.255.128 were used with a Class B network, how many subnets could exist, with how many hosts per subnet, respectively?

   Answer: E. Class B networks imply 16 network bits; the mask implies 7 host bits (7 binary 0s in the mask), leaving 9 subnet bits. $2^9 - 2$ yields 510 subnets, and $2^7 - 2$ yields 126 hosts per subnet.

3. If mask 255.255.255.240 were used with a Class C network, how many subnets could exist, with how many hosts per subnet, respectively?

   Answer: B. Class C networks imply 24 network bits; the mask implies 4 host bits (4 binary 0s in the mask), leaving 4 subnet bits. $2^4 - 2$ yields 14 subnets, and $2^4 - 2$ yields 14 hosts per subnet.

4. Which of the following IP addresses would not be in the same subnet as 190.4.80.80, mask 255.255.255.0?

   Answer: E. 190.4.80.80, mask 255.255.255.0, is in subnet 190.4.80.0, broadcast address 190.4.80.255, with a range of valid addresses between 190.4.80.1 of 190.4.80.254.

5. Which of the following IP addresses would not be in the same subnet as 190.4.80.80, mask 255.255.240.0?

   Answer: F. 190.4.80.80, mask 255.255.240.0, is in subnet 190.4.80.0, broadcast address 190.4.95.255, with a range of valid addresses of 190.4.80.1 through 190.4.95.254.

6. Which of the following IP addresses would not be in the same subnet as 190.4.80.80, mask 255.255.255.128?

   Answer: D, E, and F. 190.4.80.80, mask 255.255.255.128, is in subnet 190.4.80.0, broadcast address 190.4.80.127, with a range of valid addresses of 190.4.80.1 through 190.4.80.126.

7. Which of the following subnet masks would allow a Class B network to allow subnets to have up to 150 hosts and allow for up to 164 subnets?

   Answer: C. You need 8 bits to number up to 150 hosts because $2^7 - 2$ is less than 150, but $2^8 - 2$ is greater than 150. Similarly, you need 8 subnet bits. The only valid Class B subnet mask with 8 host and 8 subnet bits is 255.255.255.0.

8. Which of the following subnet masks would allow a Class A network to allow subnets to have up to 150 hosts and would allow for up to 164 subnets?

   Answer: B. You need 8 host bits and 8 subnet bits. Because the mask is used with a class A network, any mask with the entire second octet as part of the subnet field and with the entire fourth octet as part of the host field meets the requirement.

9. Which of the following are valid subnet numbers in network 180.1.0.0, when using mask 255.255.248.0?

   Answer: C, D, E, and F. In this case, the subnet numbers begin with 180.1.0.0 (subnet zero), and then 180.1.8.0, 180.1.16.0, 180.1.24.0, and so on, increasing by 8 in the third octet, up to 180.1.240.0 (last valid subnet) and 180.1.248.0 (broadcast subnet).

10. Which of the following are valid subnet numbers in network 180.1.0.0, when using mask 255.255.255.0?

    Answer: A, B, C, D, E, and F. In this case, the subnet numbers begin with 180.1.0.0 (subnet zero), and then 180.1.1.0, 180.1.2.0, 180.1.3.0, and so on, increasing by 1 in the third octet, up to 180.1.254.0 (last valid subnet) and 180.1.255.0 (broadcast subnet).

11. Which of the following best describes a feature of CIDR?

    Answer: A

12. The phrase "to represent hundreds or thousands of client TCP or UDP connections from different hosts as that same number of connections, but making it appear as if all connections are from one host" best describes which of the following tools?

    Answer: C

13. The phrase "grouping a large number of Class C networks into a single group, and putting a single entry for that group in an Internet router, to reduce the overall size of the IP routing table " best describes which of the following tools?

    Answer: B

14. The phrase "the use network 10.0.0.0 in an enterprise network" best describes which of the following tools?

    Answer: A

Q&A

1. Name the parts of an IP address.

   Answer: Network, subnet, and host are the three parts of an IP address. However, many people commonly treat the network and subnet parts of an address as a single part, leaving only two parts, the subnet and host parts. On the exam, the multiple-choice format should provide extra clues as to which terminology is used.

2. Define the term subnet mask. What do the bits in the mask whose values are binary 0 tell you about the corresponding IP address(es)?

   Answer: A subnet mask defines the number of host bits in an address. The bits of value 0 define which bits in the address are host bits. The mask is an important ingredient in the formula to dissect an IP address; along with knowledge of the number of network bits implied for Class A, B, and C networks, the mask provides a clear definition of the size of the network, subnet, and host parts of an address.

3. Given the IP address 134.141.7.11 and the mask 255.255.255.0, what is the subnet number?

   Answer: The subnet is 134.141.7.0. The binary algorithm is shown in the table that follows.

Address	**134.141.7.11**	1000 0110 1000 1101 **0000 0111** 0000 1011
Mask	**255.255.255.0**	1111 1111 1111 1111 **1111 1111** 0000 0000
Result	**134.141.7.0**	1000 0110 1000 1101 **0000 0111** 0000 0000

4. Given the IP address 193.193.7.7 and the mask 255.255.255.0, what is the subnet number?

   Answer: The network number is 193.193.7.0. Because this is a Class C address and the mask used is 255.255.255.0 (the default), no subnetting is in use. The binary algorithm is shown in the table that follows.

Address	**193.193.7.7**	**1100 0001 1100 0001 0000 0111 0000 0111**
Mask	**255.255.255.0**	**1111 1111 1111 1111 1111 1111 0000 0000**
Result	**193.193.7.0**	**1100 0001 1100 0001 0000 0111 0000 0000**

5. Given the IP address 200.1.1.130 and the mask 255.255.255.224, what is the subnet number?

Answer: The answer is 200.1.1.128. The table that follows shows the subnet chart to help you learn the way to calculate the subnet number without binary math. The magic number is 256 – 224 = 32.

Octet	1	2	3	4	Comments
Address	200	1	1	130	—
Mask	255	255	255	224	Interesting octet is the fourth octet (magic = 256 – 224 = 32).
Subnet number	200	1	1	128	128 is the closest multiple of the magic number not greater than 130.
First address	200	1	1	129	Add 1 to the last octet of the subnet number.
Broadcast	200	1	1	159	Subnet + magic – 1.
Last address	200	1	1	158	Subtract 1 from broadcast.

6. Given the IP address 220.8.7.100 and the mask 255.255.255.240, what is the subnet number?

Answer: The answer is 220.8.7.96. The table that follows shows the subnet chart to help you learn the way to calculate the subnet number without binary math. The magic number is 256–240=16.

Octet	1	2	3	4	Comments
Address	220	8	7	100	—
Mask	255	255	255	240	Interesting octet is the fourth octet.
Subnet number	220	8	7	96	96 is the closest multiple of the magic number not greater than 100.
First address	220	8	7	97	Add 1 to the last octet.
Broadcast	220	8	7	111	Subnet + magic – 1.
Last address	220	8	7	110	Subtract 1 from broadcast.

7. Given the IP address 134.141.7.11 and the mask 255.255.255.0, what is the subnet broadcast address?

   Answer: The broadcast address is 134.141.7.255. The binary algorithm is shown in the table that follows.

Address	**134.141.7.11**	1000 0110 1000 1101 0000 0111 0000 1011
Mask	**255.255.255.0**	1111 1111 1111 1111 1111 1111 0000 0000
Result	**134.141.7.0**	1000 0110 1000 1101 0000 0111 0000 0000
Broadcast address	**134.141.7.255**	1000 0110 1000 1101 0000 0111 **1111 1111**

8. Given the IP address 193.193.7.7 and the mask 255.255.255.0, what is the broadcast address?

   Answer: The broadcast address is 193.193.7.255. Because this is a Class C address and the mask used is 255.255.255.0 (the default), no subnetting is in use. The binary algorithm is shown in the table that follows.

Address	**193.193.7.7**	1100 0001 1100 0001 0000 0111 0000 0111
Mask	**255.255.255.0**	1111 1111 1111 1111 1111 1111 0000 0000
Result	**193.193.7.0**	1100 0001 1100 0001 0000 0111 0000 0000
Broadcast address	**193.193.7.255**	1100 0001 1100 0001 0000 0111 **1111 1111**

9. Given the IP address 200.1.1.130 and the mask 255.255.255.224, what is the broadcast address?

   Answer: The broadcast address is 200.1.1.159. The binary algorithm math is shown in the table that follows. The easy decimal algorithm is shown in the answer to an earlier question.

Address	**200.1.1.130**	1100 1000 0000 0001 0000 0001 1000 0010
Mask	**255.255.255.224**	1111 1111 1111 1111 1111 1111 1110 0000
Result	**200.1.1.128**	1100 1000 0000 0001 0000 0001 1000 0000
Broadcast address	**200.1.1.159**	1100 1000 0000 0001 0000 0001 100**1 1111**

10. Given the IP address 220.8.7.100 and the mask 255.255.255.240, what is the broadcast address?

Answer: The broadcast address is 220.8.7.111. The binary algorithm is shown in the table that follows.

Address	**220.8.7.100**	1101 1100 0000 1000 0000 0111 0110 0100
Mask	**255.255.255.240**	1111 1111 1111 1111 1111 1111 1111 0000
Result	**220.8.7.96**	1101 1100 0000 1000 0000 0111 0110 0000
Broadcast address	**220.8.7.111**	1101 1100 0000 1000 0000 0111 0110 **1111**

11. Given the IP address 134.141.7.11 and the mask 255.255.255.0, what are the assignable IP addresses in this subnet?

Answer: The subnet number is 134.141.7.0, and the subnet broadcast address is 134.141.7.255. The assignable addresses are all the addresses between the subnet and broadcast addresses, namely 134.141.7.1 to 134.141.7.254.

12. Given the IP address 193.193.7.7 and the mask 255.255.255.0, what are the assignable IP addresses in this subnet?

Answer: The subnet number is 193.193.7.0, and the network broadcast address is 193.193.7.255. The assignable addresses are all the addresses between the network and broadcast addresses, namely 193.193.7.1 to 193.193.7.254.

13. Given the IP address 200.1.1.130 and the mask 255.255.255.224, what are the assignable IP addresses in this subnet?

Answer: The subnet number is 200.1.1.128, and the subnet broadcast address is 200.1.1.159. The assignable addresses are all the addresses between the subnet and broadcast addresses, namely 200.1.1.129 to 200.1.1.158.

14. Given the IP address 220.8.7.100 and the mask 255.255.255.240, what are the assignable IP addresses in this subnet?

Answer: The subnet number is 220.8.7.96, and the subnet broadcast address is 220.8.7.111. The assignable addresses are all the addresses between the subnet and broadcast addresses, namely 220.8.7.97 to 220.8.7.110.

15. Given the IP address 134.141.7.7 and the mask 255.255.255.0, what are all the subnet numbers if the same (static) mask is used for all subnets in this network?

Answer: The answer is 134.141.1.0, 134.141.2.0, 134.141.3.0, and so on, up to 134.141.254.0. 134.141.0.0 is the zero subnet, and 134.141.255.0 is the broadcast subnet.

16. Given the IP address 220.8.7.100 and the mask 255.255.255.240, what are all the subnet numbers if the same (static) mask is used for all subnets in this network?

Answer: The answer is not as obvious in this question. The Class C network number is 220.8.7.0. The mask implies that bits 25 through 28, which are the first 4 bits in the fourth octet, comprise the subnet field. The answer is 220.8.7.16, 220.8.7.32, 220.8.7.48, and so on, through 220.8.7.224. 220.8.7.0 is the zero subnet, and 220.8.7.240 is the broadcast subnet. The following table outlines the easy decimal algorithm to figure out the subnet numbers.

Octet	1	2	3	4	Comments
Network number	220	8	7	0	—
Mask	255	255	255	240	The last octet is interesting; the magic number is 256 – 240 = 16.
Subnet zero	220	8	7	0	Copy the network number; it's the zero subnet.
First subnet	220	8	7	16	Add magic to the last subnet number's interesting octet.
Next subnet	220	8	7	32	Add magic to the previous one.
Last subnet	220	8	7	224	You eventually get her…
Broadcast subnet	220	8	7	240	…and then here, the broadcast subnet, because the next one is 256, which is invalid.

17. How many IP addresses could be assigned in each subnet of 134.141.0.0, assuming that a mask of 255.255.255.0 is used? If the same (static) mask is used for all subnets, how many subnets are there?

Answer: There will be $2^{hostbits}$, or 2^8 hosts per subnet, minus two special cases. The number of subnets will be $2^{subnetbits}$, or 2^8, minus two special cases.

Network and Mask	Number of Network Bits	Number of Host Bits	Number of Subnet Bits	Number of Hosts per Subnet	Number of Subnets
134.141.0.0, 255.255.255.0	16	8	8	254	254

18. How many IP addresses could be assigned in each subnet of 220.8.7.0, assuming that a mask of 255.255.255.240 is used? If the same (static) mask is used for all subnets, how many subnets are there?

Answer: There will be $2^{hostbits}$, or 2^4 hosts per subnet, minus two special cases. The number of subnets will be $2^{subnetbits}$, or 2^4, minus two special cases.

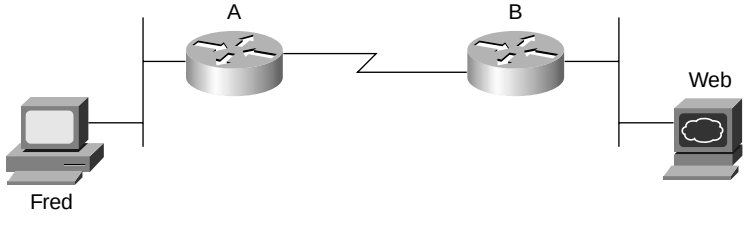
Network and Mask	Number of Network Bits	Number of Host Bits	Number of Subnet Bits	Number of Hosts per Subnet	Number of Subnets
220.8.7.0, 255.255.255. 240	24	4	4	14	14

19. You design a network for a customer, and the customer insists that you use the same subnet mask on every subnet. The customer will use network 10.0.0.0 and needs 200 subnets, each with 200 hosts maximum. What subnet mask would you use to allow the largest amount of growth in subnets? Which mask would work and would allow for the most growth in the number of hosts per subnet?

Answer: Network 10.0.0.0 is a Class A network, so you have 24 host bits with no subnetting. To number 200 subnets, you will need at least 8 subnet bits because 2^8 is 256. Likewise, to number 200 hosts per subnet, you will need 8 host bits. So, you need to pick a mask with at least 8 subnet bits and 8 host bits. 255.255.0.0 is a mask with 8 subnet bits and 16 host bits. That would allow for the 200 subnets and 200 hosts, while allowing the number of hosts per subnet to grow to $2^{16} – 2$, quite a large number. Similarly, a mask of 255.255.255.0 gives you 16 subnet bits, allowing $2^{16} – 2$ subnets, each with $2^8 – 2$ hosts per subnet.

20. Referring to Figure A-1, Fred has been configured with IP address 10.1.1.1, Router A's Ethernet has been configured with 10.1.1.100, Router A's Serial interface uses 10.1.1.101, Router B's serial uses 10.1.1.102, Router B's Ethernet uses 10.1.1.200, and the web server uses 10.1.1.201. Mask 255.255.255.192 is used in all cases. Is anything wrong with this network? What is the easiest thing that could be done to fix it? You can assume any working interior routing protocol.

Figure A-1 *Example Network for Subnetting Questions*



Answer: Router A's Ethernet interface and Fred's Ethernet should be in the same subnet, but they are not. Fred's configuration implies a subnet with IP addresses ranging from 10.1.1.1 through 10.1.1.62; Router A's Ethernet configuration implies a subnet with addresses between 10.1.1.65 and 10.1.1.126. Also, Router A's two interfaces must be in different subnets; as configured, they would be in the same subnet. So, the solution is to change Router A's Ethernet IP address to something between 10.1.1.1 and 10.1.1.62, making it be in the same subnet as Fred.

21. Referring to Figure A-1, Fred has been configured with IP address 10.1.1.1, mask 255.255.255.0; Router A's Ethernet has been configured with 10.1.1.100, mask 255.255.255.224; Router A's serial interface uses 10.1.1.129, mask 255.255.255.252; Router B's serial uses 10.1.1.130, mask 255.255.255.252; Router B's Ethernet uses 10.1.1.200, mask 255.255.255.224; and the web server uses 10.1.1.201, mask 255.255.255.224. Is anything wrong with this network? What is the easiest thing that could be done to fix it? You can assume any working interior routing protocol.

Answer: Fred's configuration implies a subnet with a range of addresses from 10.1.1.1 through 10.1.1.254, so he thinks that Router A's Ethernet interface is in the same subnet. However, Router A's configuration implies a subnet with addresses from 10.1.1.97 through 10.1.1.126, so Router A does not think that Fred is on the same subnet as Router A's Ethernet. Several options exist for fixing the problem. You could change the mask used by Fred and Router A's Ethernet to 255.255.255.128, which makes them both reside in the same subnet.

22. Referring to Figure A-1, Fred has been configured with IP address 10.1.1.1, mask 255.255.255.240; Router A's Ethernet has been configured with 10.1.1.2, mask 255.255.255.240; Router A's Serial interface uses 10.1.1.129, mask 255.255.255.252; Router B's serial uses 10.1.1.130, mask 255.255.255.252; Router B's Ethernet uses 10.1.1.200, mask 255.255.255.128; and the web server uses 10.1.1.201, mask 255.255.255.128. Is anything wrong with this network? What is the easiest thing that could be done to fix it? You can assume any working interior routing protocol.

Answer: Router B's configuration implies a subnet with a range of addresses from 10.1.1.129 to 10.1.1.130 on the serial link, and 10.1.1.129 to 10.1.1.254 on the Ethernet. So, the subnets overlap. One solution would be to configure Router B and the web server's masks to 255.255.255.192, which would change the subnet so that the valid addresses would be between 10.1.1.193 and 10.1.1.254.

23. What are the valid private IP network numbers, according to RFC 1918?

    Answer: Network 10.0.0.0, Class B networks that from 172.16.0.0 through 172.31.0.0, and Class C networks beginning with 192.168.

24. How large are IPv6 addresses?

    Answer: 128 bits long.

25. How does CIDR help reduce the size of Internet routing tables?

    Answer: By using a routing protocol that exchanges the mask as well as the subnet/network number, a classless view of the number can be attained. By advertising many networks as a single route, the routing table can be shortened. For instance, 198.0.0.0/8 (198.0.0.0, mask 255.0.0.0) defines a set of addresses whose first 8 bits are equal to decimal 198. Instead of the more than 65,000 routes needed to list a route for each class C network that starts with 198, CIDR allows those routes to be represented by a single route.

Chapter 13

"Do I Know This Already?" Quiz

1. Which of the following commands is valid for the configuration of IP address 10.1.1.1, mask 255.255.255.0?

   Answer: C

2. Which of the following must be true before Cisco IOS Software adds a connected route to the routing table?

   Answer: A and E. The router adds the subnet number of the directly connected interface to the routing table after the IP address is configured. The interface must be operational before the route is added.

3. Which of the following represents the same ideas as mask 255.255.240.0?

   Answer: C. The answers all use prefix notation, which represents the subnet mask by stating the number of binary 1s in the mask.

4. What command brings up an interface that previously was administratively disabled?

   Answer: A. shutdown disables the interface, and no shutdown brings it back up.

5. Imagine that a PC is attached to the same Ethernet as a router. The PC makes a DNS request for host name Fred, and the PC gets a reply showing IP address 10.1.1.1. What command could be issued on the router to list the information learned in that DNS request and reply?

   Answer: D. The show hosts command lists the host name configured in the router or names learned by the router from the DNS as a result of a command on the router using the name. The router does not learn about names as a result of DNS requests from an end user.

6. Imagine that a neighboring router's host name is Hannah. Which of these commands could tell you information about the IOS version on Hannah, without Telnetting to Hannah?

   Answer: H and I. CDP discovers information about neighbors. show cdp gives you several options that display more or less information, depending on the parameters used.

7. What CDP command(s) could identify the model of hardware of a neighbor?

   Answer: F, G, and H

8. Imagine that you used a **ping** command successfully. What messages would have been sent by the **ping** command?

   Answer: B

9. Imagine that you just erased all the configuration on a router and reloaded it. To configure the router to use a DNS at IP address 10.1.1.1, which of the following commands is required?

   Answer: A

10. Imagine that you just logged in to the console of router R1 and then Telnetted to R2. What must you type to suspend your Telnet connection, going back to R1?

    Answer: C

Q&A

1. Create a minimal configuration enabling IP on each interface on a 2501 router (two serial, one Ethernet). The NIC assigned you network 8.0.0.0. Your boss says that you need, at most, 200 hosts per subnet. You decide against using VLSM. Your boss also says to plan your subnets so that you can have as many subnets as possible rather than allow

for larger subnets later. When choosing the actual IP address values and subnet numbers, you decide to start with the lowest numerical values. Assume that point-to-point serial links will be attached to this router.

```
interface ethernet 0
ip address 8.0.1.1 255.255.255.0
interface serial 0
ip address 8.0.2.1 255.255.255.0
interface serial 1
ip address 8.0.3.1 255.255.255.0
```

Answer: The zero subnet was not used in this solution. If desired, the ip subnet-zero global command could have been used, enabling subnet 8.0.0.0/24 as well as subnets 8.0.1.0/24 and 8.0.2.0/24 to be used as the three subnets in the configuration.

2. In the previous question, what would be the IP subnet of the link attached to serial 0? If another user wanted to answer the same question but did not have the enable password, what command(s) might provide this router's addresses and subnets?

   Answer: The attached subnet is 8.0.2.0, 255.255.255.0. The show interface, show ip interface, and show ip interface brief commands would supply this information, as would show ip route. The show ip route command would show the actual subnet number instead of the address of the interface.

3. What must be done to make the output of the **show ip route** command list subnet masks in decimal format instead of prefixes? In what mode would you use the command?

   Answer: You must use the terminal ip netmask-format decimal command in enable mode.

4. What are the differences between the **clock rate** and **bandwidth** commands?

   Answer: clock rate sets the physical (Layer 1) actual transmission rate, in bits per second, and only when a DCE cable has been plugged into that interface. The bandwidth command, with units of kbps, does not affect Layer 1 transmission rates. Instead, it is used by Cisco IOS Software as its understanding of the Layer 1 rate, for purposes such as calculation of routing protocol metrics.

5. Compare and contrast the commands used to set the enable, console, and telnet passwords on a router.

   Answer: The password command sets the console and telnet password. When used as a line console 0 subcommand, it sets the console password; under line vty 0 4, it sets the telnet password. The enable password can be set with the enable password or enable secret commands, with the enable secret password taking precedence if both are configured.

6. In the output of **show ip route**, when a C shows up in the left side of the output on a line for a particular route, what does that mean?

   Answer: C means "connected." This means that the route was learned by this router because it has an operational interface that is connected directly to that subnet.

7. Define the term prefix notation. Give two examples.

   Answer: The representation of a subnet mask with a slash character (/), followed by a number that represents the number of binary 1s in the mask. For example, /16 means the same thing as 255.255.0.0, and /22 means the same thing as 255.255.252.0.

8. What does ICMP stand for? To which OSI layer would you consider this protocol to apply most closely?

   Answer: Internet Control Message Protocol. ICMP is considered a Layer 3 protocol because it is used for control and management of IP.

9. Identify two methods to tell a router to ask for name resolution from two different name servers.

   ip name-server 1.1.1.1 2.2.2.2

   or

   ip name-server 1.1.1.1

   ip name-server 2.2.2.2

   Answer: Both methods tell the router to first try the name server at 1.1.1.1 and then try the name server at 2.2.2.2.

10. What keyboard sequence suspends a Telnet session in a Cisco router?

    Answer: Ctrl-Shift-6, followed by x.

11. What two commands, and what part the command output, tells you which suspended Telnet connection will be reconnected if you just press the Enter key, without any characters typed on the command line?

    Answer: show sessions and where. Both commands supply the same information. The suspended session with an asterisk in the left side of the output line designates the session to which you would be connected if you just pressed Return, with no characters on the command line.

12. Imagine that you typed a **ping** command and got 5 "**!**" back. What type of messages were sent through the network? Be as specific as possible.

    Answer: ICMP echo request messages were sent by the ping command, with the remote host replying with five ICMP echo reply messages.

13. How do you make a router not ask for DNS resolution from a name server?

    Answer: By using the no ip domain-lookup global configuration command.

14. Imagine that you are just logged in at the console of R1, and you Telnet to routers R2, R3, and R4 in succession, but you suspended your Telnet connection each time—in other words, all three Telnet connections go from R1 to the other three routers, respectively. What options do you have for reconnecting to R2?

    Answer: You can use the resume 1 command or just use the 1 command.

15. Imagine that you are just logged in at the console of R1, and you Telnet to routers R2, R3, and R4 in succession, but you suspended your Telnet connection each time—in other words, all three Telnet connections go from R1 to the other three routers, respectively. What options do you have for reconnecting to R4?

    Answer: You can use the resume 3 command or just use the 3 command. Or, you can simply press Enter, which resumes your connection to the last suspended Telnet connection—in this case, R4.

16. List the five key pieces of information that can be gathered using CDP, as mentioned in the chapter.

    Answer: Device identifier, address list, port identifier, capabilities list, and platform.

17. Imagine a network with Switch1, connected to Router1, with a point-to-point serial link to Router2, which, in turn, is connected to Switch2. Assuming that you are logged into R1, what commands could be used to find the IP addresses of Router2 and Switch1 without logging in to either device?

Answer: On Router1, you could use either the show cdp neighbor detail command or the show cdp entry command. Both commands list IP addresses of the neighboring devices, assuming that CDP is up and working.

18. Imagine that a network with Switch1 is connected to Router1, with a point-to-point serial link to Router2, which, in turn, is connected to Switch2. You can log in only to Switch1. Which of the other devices could Switch1 learn about using CDP? Why?

    Answer: Switch1 could learn about only Router1 because CDP learns information about only devices that are connected to the same data link.

19. What command lists a brief one-line description of CDP information about each neighbor?

    Answer: The show cdp neighbor command.

Chapter 14

"Do I Know This Already?" Quiz

1. Which of the following routing protocols are considered to use distance vector logic?

   Answer: A and B

2. Which of the following routing protocols are considered to use link-state logic?

   Answer: E and G

3. Which of the following routing protocols use a metric that is, by default, at least partially affected by link bandwidth?

   Answer: C, D, and E

4. Which of the following interior routing protocols support VLSM?

   Answer: B, D, E, and F

5. Which of the following situations would cause RIP to remove all the routes learned from a particular neighboring router?

   Answer: B. Distance vector protocols rely on regular receipt of routing updates from their neighbors to continue believing that the routes through that neighbor are still valid.

6. Which of the following interior routing protocols are considered to be capable of converging quickly?

   Answer: D, E, and F

7. Which of the following interior routing protocols use hop count as their metric?

   Answer: A and B

8. What update timer is used by IGRP?

   Answer: E

Q&A

1. Which interior IP routing protocols covered in this chapter support VLSM?

   Answer: RIP-2, EIGRP, OSPF, Integrated IS-IS, and BGP.

2. Which IP routing protocols covered in this chapter use distance vector logic?

   Answer: RIP-1, RIP-2, and IGRP.

3. Which interior IP routing protocols covered in this chapter are considered to converge quickly?

   Answer: EIGRP, OSPF, and Integrated IS-IS.

4. Compare distance vector and link-state protocols in terms of what information is sent in routing updates.

   Answer: Distance vector protocols send sparse information, typically describing a subnet and a metric for each route. Link-state protocols send much more detailed topology information, describing each router and each link so that every router knows a full conceptual picture of the network.

5. List three similarities between EIGRP's balanced hybrid logic and link-state logic.

   Answer: Fast convergence, neighbor discovery before sending routing information, not sending of full updates on a regular period, some topology tables built in addition to the IP routing table.

6. Explain the basic concept behind why some routing protocols support VLSM and some do not.

   Answer: VLSM implies that different subnet masks are used for different subnets of the same network. To advertise subnets that have different sizes, the routing protocol must include the subnet mask information for each subnet in the routing updates. Routing protocols that do not support VLSM do not include the mask in the routing updates.

7. Explain the difference between interior and exterior routing protocols.

   Answer: Interior routing protocols are designed to advertise detailed routing information about each subnet, typically inside a single company or organization. Exterior routing protocols are designed to advertise information about how to reach different organizations' networks through the Internet, and they purposefully try to reduce the detailed routing information to reduce the number of routes in Internet routers' routing tables.

8. Explain the difference between full and partial routing updates.

   Answer: Full routing updates include information about each subnet during each update interval. Partial updates just include changed routes, such as newly learned subnets and subnets whose routes have failed.

9. Define the term balanced hybrid in relation to the terms distance vector and link state.

   Answer: Balanced hybrid is a term used to refer to the logic used by EIGRP. The logic can be viewed as a combination of features like those of distance vector protocols and link-state protocols.

10. Compare and contrast the types of information sent in distance vector routing updates versus link-state routing updates.

    Answer: Distance vector routing updates contain a subnet number and a metric for each route. Link-state updates define much more detailed information, such as the identity of each router and which subnets each router is connected to. Therefore, the information in link-state updates is much more detailed than the equivalent information with distance vector updates. The more detailed information allows a link-state protocol to build a mathematical representation of the network topology, whereas distance vector protocols simply know that subnets exist and where to send packets to reach those subnets.

11. What term describes the underlying logic behind the OSPF routing protocol?

    Answer: Link state.

Chapter 15

"Do I Know This Already?" Quiz

1. Which of the following acronyms identifies a voice codec used to encode analog voice signals into a 64-kbps digital data stream?

   Answer: D

2. How many DS0 channels are in a DS1 in the United States?

   Answer: E

3. Which of the following best describes the function of demodulation by a modem?

   Answer: D. Modems demodulate an analog signal sent by the phone company. The goal is to re-create the original bits sent by the other modem, so the demodulation function converts the analog signal into the bits that it was intended to represent.

4. Which of the following modem standards do not support 56-kbps speeds downstream?

   Answer: A, B, C, F, G, and H

5. Which of the following terms best describes features of an ISDN PRI in Europe?

   Answer: E. PRIs in Europe are based on E1 circuits, which have 32 DS0 channels. One channel is reserved for framing, and one channel is used for a D channel, leaving 30 B channels.

6. Imagine that you plug an analog phone into an ISDN modem and call a friend at her house, where she uses an analog phone using plain-old telephone service (POTS). At which of the following points in a network will a voice codec be used?

   Answer: B and D. Because the ISDN modem sends only digital signals over the local loop, it must convert the analog voice from the phone connected to it into digital voice using a voice codec.

7. What does the letter B stand for in the ISDN term *B channel*?

   Answer: A

8. Which of the following DSL standards has a limit of 18,000 feet for the length of the local loop?

   Answer: C

9. Imagine a local phone line from a house to a local telco CO. When the customer at that house requests DSL service, what type of device does the telco move the CO end of the local line to?

   Answer: A. The CO uses a DSLAM to terminate local loops that use DSL. A DSL router or DSL modem is connected to the local loop at the subscriber (home) location.

10. Which of the following protocols are used by DSL modem and routers for data link layer functions?

    Answer: A, B, and C. DSL calls for the use of PPP over ATM (PPPoA) over the DSL part of the network. PPP can extend to the PCs at the home location using PPP over Ethernet (PPPoE).

11. Which of the following protocols is used by cable modems for data link layer functions?

    Answer: E. Multimedia Cable Network Services (MCNS) defines a MAC layer that also uses IEEE 802.2 as part of the data link layer.

12. Which of the following protocols are used by a cable modem for the upstream data?

    Answer: B and E

13. Which of the following remote access technologies uses ATM, Ethernet, and PPP as data-link protocols?

    Answer: C

14. Which of the following remote access technologies support specifications that allow both symmetric speeds and asymmetric speeds?

    Answer: A and C. ISDN always uses symmetric speeds, and cable modems always use asymmetric speeds.

15. Which of the following remote access technologies, when used to connect to an ISP, is considered to be an "always on" service?

    Answer: C and D. Analog modems and ISDN lines must signal or dial to set up a circuit before any data can be passed, whereas DSL and cable modems do not do this.

Q&A

1. What do ISDN, BRI, and PRI stand for?

   Answer: ISDN stands for Integrated Services Digital Network. BRI stands for Basic Rate Interface. PRI stands for Primary Rate Interface.

2. How many bearer channels are in a BRI? What about a PRI in North America? What about a PRI in Europe?

   Answer: BRI uses two bearer channels and one signaling channel (2B+D). PRI uses 23B+D in North America and 30B+D in Europe. The signaling channel on BRI is a 16-kbps channel; on PRI, it is a 64-kbps channel.

3. Define what a voice codec does, and explain why a PCM codec needs 64 kbps for a single voice call.

   Answer: Voice codecs code and decode voice signals, converting from analog to digital, and digital to analog. A PCM codec samples the analog signal 8000 times per second, generating an 8-bit code to represent each sample. So, 64,000 bits are needed for a single second of voice.

4. Two terms were shortened and combined to first create the word modem. Identify those two words and describe what each word means.

   Answer: The term modem is formed as a combination of the words modulation and demodulation. Modulation means to vary or change a wave form to encode information. A modem varies an analog electrical signal to encode information, representing binary digits, onto an analog signal. Modulation refers to the creation of the analog signal based on a string of bits, and demodulation simply refers to a modem performing the reverse process upon receiving the analog signal.

5. Define what the terms symmetric and asymmetric mean in relation to modem specifications. Also explain why asymmetric might be a better option.

   Answer: Symmetric means that the speed in each direction of flow is the same, whereas asymmetric means that the speed in one direction is faster than the other. Asymmetric speeds might be a good choice because typical traffic flows require a much greater amount of data to flow in one direction, typically from a server to a client. Asymmetric speeds allow the speed in one direction to be faster than it could be with symmetric speeds, accommodating the need for more bandwidth in one direction.

6. Compare the V.90 and V.92 modem specifications.

   Answer: Based on this chapter, V.92 is an improvement over the V.90 standard. V.92 supports symmetric and asymmetric speeds, whereas V.90 supports only asymmetric speeds. The upstream speed has been increased from 33 kbps up to 48 kbps. It supports modem-on-hold, which allows the user to accept a voice call in response to a call-waiting signal, putting the modem connection on hold. It also senses the correct operational speed more quickly than V.90.

7. Compare analog modems, ISDN BRIs, DSL, and cable modems in terms of concurrent support for voice and data.

   Answer: Analog modems do not support concurrent voice and data transmission. ISDN and DSL both support simultaneous voice and data over the same local loop (local phone line). Cable allows simultaneous data, voice, and TV reception.

8. Compare analog modems, ISDN BRIs, DSL, and cable modems in terms of whether the data service is always on.

   Answer: Analog modems and ISDN BRIs must signal to set up a circuit, so any data capabilities, such as Internet connectivity, are not "always on." DSL and cable do not require any signaling to set up a circuit—in fact, no circuit is needed in the PSTN to support these technologies, so these services are "always on."

9. List some of the pros and cons regarding the use of analog modems for remote access.

   Answer: Modems have the great advantage of being the most pervasively available remote access technology. The history of modems is long, with modems growing to be a very reliable choice for remote access. Speeds have improved over the years, with compression technology increasing the effective throughput to beyond 100 kbps. The biggest negatives about using modems include their relatively low speed and the fact that you cannot use the phone at the same time as you send data.

10. List some of the pros and cons regarding the use of ISDN for remote access.

    Answer: ISDN's advantages include the capability to support voice calls concurrently with a data call. Also, ISDN can be used over the local telco loop, with no significant distance limitations. And it provides more bandwidth than do modems, particularly with both B channels dialed to the same remote site. ISDN does have a few disadvantages, with the biggest disadvantage being the lower speeds than DSL or cable.

11. List some of the pros and cons regarding the use of DSL for remote access.

    Answer: DSL provides high-speed Internet access to the home, exceeding downstream speeds of 1 Mbps. It supports concurrent voice and data, with the data service always being turned on—no dialing is required. And the service speed does not degrade when more users are added to the network. However, DSL simply will not be available to some people, based on the distance to the local CO or the availability of DSL services from the local telco. Also, even when the home is close enough to the CO, sites farther from the CO might run slower than sites closer to the CO.

12. Define what the acronym DSLAM stands for, and explain the concept behind how a DSLAM allows voice and data to flow over the same local loop phone line.

Answer: DSLAM stands for DSL access multiplexer, with DSL meaning digital subscriber line. The DSLAM is connected to the local loop, splitting off the voice frequencies (0 to 4000 Hz) for the voice switch in the CO. It also interprets the higher frequencies as encoded digital signals, receiving the ATM cells sent over that digital signal, and forwards those ATM cells to the appropriate router.

13. Which of the DSL standards is the most common in the United States today? What is the range of upstream and downstream speeds for that type of DSL, as well as the maximum distance of the local loop?

Answer: ADSL, meaning asynchronous DSL, is the most popular. The downstream speeds range from 1.5 to 8 Mbps, with upstream speeds from 64 to 800 kbps. The maximum distance is 18,000 feet (approximately 5500 meters).

14. What protocols are used by DSL at the data link layer?

Answer: ATM, Ethernet, and PPP.

15. Imagine that Andy and Barney are neighbors, and they both use cable modems. Describe the type of traffic that they could generate that could cause collisions, and tell what is done to help prevent those collisions.

Answer: Downstream data never can cause a collision with upstream data because the two are sent in different frequency ranges. Because only the head end sends downstream data, no collisions can occur. Upstream data from all subscribers uses the same frequency range, so data sent to the head end by Andy and Barney could collide. Cable standards use a feature called time-division multiple access (TDMA) to assign time slots to each subscriber. This prevents most collisions so no collisions should occur.

16. Name the four different Layer 1 encoding methods defined for use by cable modems. For each one, list whether it is used for upstream data, downstream data, or both.

Answer: QAM-64 and QAM-256 are both available for use as downstream encoding methods. QAM-16 and QPSK are both available for upstream encoding.

17. Which of the four different remote access technologies support IP, TCP, UDP, and the rest of the higher-layer TCP/IP protocols?

Answer: All of them!

18. Compare and contrast the cabling used by an analog modem and a DSL router/modem when connecting to the local phone company line. Identify the purpose of each pin on the connector.

Answer: Both use a cable with two wires, using an RJ-11 connector. Pin 3 is used for transmit; pin 4 is used for receive.

19. Compare and contrast the cabling used by an ISDN modem and a cable modem when connecting to the local phone company line or cable drop line. Identify the purpose of each pin on the connector.

Answer: ISDN uses a four-wire cable using an RJ-45 connector. The pinouts: pins 3 and 6 for transmit, and pins 4 and 5 for receive. Cable modems use coaxial cable with a single conductor, so there are no pins. The round connector on the end of the cable is called an f-connector.

20. List four standards bodies that have been involved in the development of DSL standards.

Answer: ANSI, IEEE, ETSI, ITU.

APPENDIX B

Decimal to Binary Conversion Table

Decimal Value	Binary Value	Decimal Value	Binary Value
0	0000 0000	23	0001 0111
1	0000 0001	24	0001 1000
2	0000 0010	25	0001 1001
3	0000 0011	26	0001 1010
4	0000 0100	27	0001 1011
5	0000 0101	28	0001 1100
6	0000 0110	29	0001 1101
7	0000 0111	30	0001 1110
8	0000 1000	31	0001 1111
9	0000 1001	32	0010 0000
10	0000 1010	33	0010 0001
11	0000 1011	34	0010 0010
12	0000 1100	35	0010 0011
13	0000 1101	36	0010 0100
14	0000 1110	37	0010 0101
15	0000 1111	38	0010 0110
16	0001 0000	39	0010 0111
17	0001 0001	40	0010 1000
18	0001 0010	41	0010 1001
19	0001 0011	42	0010 1010
20	0001 0100	43	0010 1011
21	0001 0101	44	0010 1100
22	0001 0110	45	0010 1101

continues

Decimal Value	Binary Value	Decimal Value	Binary Value
46	0010 1110	76	0100 1100
47	0010 1111	77	0100 1101
48	0011 0000	78	0100 1110
49	0011 0001	79	0100 1111
50	0011 0010	80	0101 0000
51	0011 0011	81	0101 0001
52	0011 0100	82	0101 0010
53	0011 0101	83	0101 0011
54	0011 0110	84	0101 0100
55	0011 0111	85	0101 0101
56	0011 1000	86	0101 0110
57	0011 1001	87	0101 0111
58	0011 1010	88	0101 1000
59	0011 1011	89	0101 1001
60	0011 1100	90	0101 1010
61	0011 1101	91	0101 1011
62	0011 1110	92	0101 1100
63	0011 1111	93	0101 1101
64	0100 0000	94	0101 1110
65	0100 0001	95	0101 1111
66	0100 0010	96	0110 0000
67	0100 0011	97	0110 0001
68	0100 0100	98	0110 0010
69	0100 0101	99	0110 0011
70	0100 0110	100	0110 0100
71	0100 0111	101	0110 0101
72	0100 1000	102	0110 0110
73	0100 1001	103	0110 0111
74	0100 1010	104	0110 1000
75	0100 1011	105	0110 1001

Decimal Value	Binary Value	Decimal Value	Binary Value
106	0110 1010	136	1000 1000
107	0110 1011	137	1000 1001
108	0110 1100	138	1000 1010
109	0110 1101	139	1000 1011
110	0110 1110	140	1000 1100
111	0110 1111	141	1000 1101
112	0111 0000	142	1000 1110
113	0111 0001	143	1000 1111
114	0111 0010	144	1001 0000
115	0111 0011	145	1001 0001
116	0111 0100	146	1001 0010
117	0111 0101	147	1001 0011
118	0111 0110	148	1001 0100
119	0111 0111	149	1001 0101
120	0111 1000	150	1001 0110
121	0111 1001	151	1001 0111
122	0111 1010	152	1001 1000
123	0111 1011	153	1001 1001
124	0111 1100	154	1001 1010
125	0111 1101	155	1001 1011
126	0111 1110	156	1001 1100
127	0111 1111	157	1001 1101
128	1000 0000	158	1001 1110
129	1000 0001	159	1001 1111
130	1000 0010	160	1010 0000
131	1000 0011	161	1010 0001
132	1000 0100	162	1010 0010
133	1000 0101	163	1010 0011
134	1000 0110	164	1010 0100
135	1000 0111	165	1010 0101

continues

Decimal Value	Binary Value	Decimal Value	Binary Value
166	1010 0110	196	1100 0100
167	1010 0111	197	1100 0101
168	1010 1000	198	1100 0110
169	1010 1001	199	1100 0111
170	1010 1010	200	1100 1000
171	1010 1011	201	1100 1001
172	1010 1100	202	1100 1010
173	1010 1101	203	1100 1011
174	1010 1110	204	1100 1100
175	1010 1111	205	1100 1101
176	1011 0000	206	1100 1110
177	1011 0001	207	1100 1111
178	1011 0010	208	1101 0000
179	1011 0011	209	1101 0001
180	1011 0100	210	1101 0010
181	1011 0101	211	1101 0011
182	1011 0110	212	1101 0100
183	1011 0111	213	1101 0101
184	1011 1000	214	1101 0110
185	1011 1001	215	1101 0111
186	1011 1010	216	1101 1000
187	1011 1011	217	1101 1001
188	1011 1100	218	1101 1010
189	1011 1101	219	1101 1011
190	1011 1110	220	1101 1100
191	1011 1111	221	1101 1101
192	1100 0000	222	1101 1110
193	1100 0001	223	1101 1111
194	1100 0010	224	1110 0000
195	1100 0011	225	1110 0001

Decimal Value	Binary Value	Decimal Value	Binary Value
226	1110 0010		
227	1110 0011		
228	1110 0100		
229	1110 0101		
230	1110 0110		
231	1110 0111		
232	1110 1000		
233	1110 1001		
234	1110 1010		
235	1110 1011		
236	1110 1100		
237	1110 1101		
238	1110 1110		
239	1110 1111		
240	1111 0000		
241	1111 0001		
242	1111 0010		
243	1111 0011		
244	1111 0100		
245	1111 0101		
246	1111 0110		
247	1111 0111		
248	1111 1000		
249	1111 1001		
250	1111 1010		
251	1111 1011		
252	1111 1100		
253	1111 1101		
254	1111 1110		
255	1111 1111		

APPENDIX C

Using the Simulation Software for the Hands-on Exercises

One of the most important skills required for passing the INTRO, ICND, and CCNA exams is the ability to configure Cisco routers and switches with confidence. In fact, one of the reasons that this book is relatively long is the effort put into explaining the commands, the output of **show** commands, and how the commands work together. Many CCNA candidates simply do not get a lot of hands-on experience, so this book is designed to help those who do not have real gear.

Another way to practice and develop hands-on skills is to use a simulator. A company called Boson Software, Inc. (www.boson.com) produces a network simulation product called NetSim™. The full NetSim product, available over the Internet from Boson, contains a large number of lab exercises and support for a large number of devices. You can even design your own network topology from scratch! It is a very impressive product.

The CD included with this book has a version of NetSim built specifically for this book. This version of NetSim includes support for several lab exercises and lab scenarios that were written just for this book. Although the software lets you work through these exercises, it is a limited-feature demo version of the actual NetSim software, which requires paid registration for full functionality. The full-feature version of NetSim includes a large set of other labs, including labs appropriate for the CCNP exams. You can also build a network topology with the full version of the product, so you can try any of the examples in this book or to experiment with networks.

This short appendix explains the following:

- How to get to the NetSim user interface on the CD
- What hands-on exercises in the book can be performed using this special edition of NetSim

Accessing NetSim from the CD

Accessing NetSim from the CD is relatively simple. Put the CD in the CD drive, and the software on the CD starts. (If it doesn't, run the command **autorun.exe** that is on the CD's root directory.) After logging in, select the Hands-on Practice Exercises and NetSim Demo Software link in the main menu. Another menu opens that allows you to view the CD-only appendixes of labs and to start the NetSim software.

NetSim lets you pick which lab topology to load. You pick a lab topology, and you next see the NetSim user interface.

You can think of what you see next as a real lab, with real routers and switches. The cabling topology and interface numbers match the labs and scenarios in this book. So you can access the devices and start entering commands!

The NetSim software includes the NetSim user guide, which helps you figure out how to navigate and use the NetSim product. (Just select "help" and "User guide" from NetSim.) However, the user manual does not tell you anything about the hands-on exercises you can do with this special version of NetSim! You can always just experiment using NetSim, trying all the commands you can think of, but remember that this is a limited-use version of the software, so not all commands are enabled. If you want some instructions on good things to try to do with the simulator, read the next section. It lists all the labs and scenarios in this book that can be performed using NetSim!

Hands-on Exercises Available with NetSim

This book includes two main types of exercises that can be duplicated using real gear or the special NetSim network simulator—scenarios and labs. You can improve your hands-on skills whether you perform these exercises using real gear, perform them using NetSim, or just read through the exercises.

Scenarios

In this Cisco Press Exam Certification Guide series, scenarios include some form of a problem statement, asking you to solve the problem. Then a suggested solution is shown, with an explanation of some of the pitfalls you might have encountered with your answer. Many of these scenarios include configuration and EXEC commands, but some do not. These scenarios are designed so that if you don't have access to real hardware, you can still learn more about the commands on routers and switches. These same scenarios can also be performed using NetSim!

Labs

This book also includes lab exercises, which follow a format typical of labs used in networking courses. These labs give you more guidance than do the scenarios. For instance, the scenarios simply state a goal, such as "Configure these three routers to support a full mesh of PVCs," whereas a lab gives you instructions for each step you need to take to configure the network. You simply read the lab instructions, and the lab guides you through the steps required to configure a network based on a stated set of requirements.

As with the scenarios, you can perform these labs on real gear or using the special NetSim build included with the CD that comes with this book. You can also just read through the labs and their solutions if your time is limited, but you might want to at least try to write down the solution before looking at the answer!

Listing of the Hands-on Exercises

To best use NetSim, you should first pick a particular lab or scenario. You might even want to print a copy if the lab or scenario is in one of the CD-only appendixes. Then you can bring up NetSim and select the corresponding NetSim lab topology that matches the lab or scenario. NetSim creates a simulated network that matches the lab or scenario, so all you have to do is start entering commands, just as if it were a real network with real gear!

The scenarios and labs are located in a couple different places. First, Chapter 18, "Final Preparation," includes one scenario. It covers a lot of different topics from the book. The CD contains a scenarios appendix (CD-only Appendix B, "Scenarios") and a lab appendix (CD-only Appendix C, "Hands-on Lab Exercises"). These scenarios and labs focus on a more specific set of topics. If you plan to use NetSim frequently, you should probably print the CD-only Appendixes B and C.

In CD-only Appendix B, the scenarios are numbered in a way to help remind you of the corresponding chapter in the book. For instance, Scenario 1 reinforces topics covered in Chapter 7, "Operating Cisco Routers," and Scenario 3 covers the same commands covered in Chapter 8, "Operating Cisco LAN Switches."

Table C-1 lists the different scenarios and labs from this book that can be performed using NetSim. Note that some of the scenarios in CD-only Appendix B cannot be performed on the simulator, mainly because those scenarios do not ask you to implement anything on a network, making the simulator unnecessary. So Table C-1 lists the scenarios and labs that can be performed using NetSim.

Table C-1 *Scenarios and Labs That Can Be Performed Using NetSim*

Scenario or Lab	Location	Topic	NetSim Lab Number
Scenario 1*	Chapter 16	Comprehensive scenario for topics in this book	1
Scenario 3	CD-only Appendix B	LAN switch basic configuration	2
Scenario 6	CD-only Appendix B	Subnet design with a Class B network	3
Lab 1*	CD-only Appendix C	Router command-line interface familiarization	4
Lab 2*	CD-only Appendix C	2950 series switch command-line interface familiarization	5
Lab 3*	CD-only Appendix C	Basic router IP configuration and management navigation	6

* Labs with an asterisk can be performed with the limited-function version of NetSim included with this book. To perform the other lab scenarios, you will need to purchase the full version of NetSim.

How You Should Proceed with NetSim

You can bring up NetSim and dive right in. However, here a a few suggestions before you are ready to do all the labs:

- Bring up NetSim now, and make sure you can at least get to a router command prompt, using the PC you will most likely use when studying. That way, when you are ready to do your first lab or scenario, you know you have worked out any installation issues.
- If you intend to do most of the labs and scenarios, you might want to print CD-only Appendixes B and C.
- Decide if you prefer to do the labs and scenarios after reading the book or as you go along.
- If you want to do the labs as you progress through the book, refer to Table C-2 for my suggestions on the best time to do the labs and scenarios.

Table C-2 *The Best Time to Do Each Lab or Scenario Using NetSim*

Scenario or Lab	Location	Topic	After Reading Which Chapter
Scenario: Chapter 16 of this book	Chapter 16	Comprehensive scenario for topics in this book	16
Scenario 3	CD-only Appendix B	LAN switch basic configuration	8
Scenario 6	CD-only Appendix B	Subnet design with a Class B network	12
Lab 1	CD-only Appendix C	Router command-line interface familiarization	7
Lab 2	CD-only Appendix C	2950 series switch command-line interface familiarization	8
Lab 3	CD-only Appendix C	Basic router IP configuration and management navigation	13

Considerations When Using NetSim

NetSim is a wonderful product, and you can certainly get a lot of good hands-on experience using the NetSim product that is included with the book. However, like any simulator product, it does not mimic a network with 100% accuracy. Some situations are difficult to simulate. For instance, it is very challenging to simulate the output of **debug** commands, because the simulator is not actually running IOS. If you intend to use NetSim, please download the latest list of hints, tips, and caveats from www.ciscopress.com/1587200945.

GLOSSARY

10BASE-T The 10-Mbps baseband Ethernet specification using two pairs of twisted-pair cabling (Categories 3, 4, or 5): One pair transmits data and the other receives data. 10BASE-T, which is part of the IEEE 802.3 specification, has a distance limit of approximately 100 m (328 feet) per segment.

802.1Q The IEEE standardized protocol for VLAN trunking.

AAA Authentication, Authorization, and Accounting. Authentication confirms the identity of the user or device. Authorization determines what the user or device is allowed to do. Accounting records information about access attempts, including inappropriate request.

accounting In security, the recording of access attempts. *See* AAA.

ADSL Asymmetric digital subscriber line. One of many DSL technologies, ADSL is designed to deliver more bandwidth downstream (from the central office to the customer site) than upstream.

AppleTalk DDP The AppleTalk Data Delivery Protocol (DDP) is the AppleTalk equivalent of the IP protocol. It defines a 24-bit address, with 16 bits defining the network and 8 bits defining the node.

ARP Address Resolution Protocol. An Internet protocol used to map an IP address to a MAC address. Defined in RFC 826.

asynchronous The lack of an imposed time ordering on a bit stream. Practically, both sides agree to the same speed, but there is no check or adjustment of the rates if they are slightly different. However, because only 1 byte per transfer is sent, slight differences in clock speed are not an issue. A start bit is used to signal the beginning of a byte.

ATM Asynchronous Transfer Mode. The international standard for cell relay in which multiple service types (such as voice, video, or data) are conveyed in fixed-length (53-byte) cells. Fixed-length cells allow cell processing to occur in hardware, thereby reducing

transit delays. ATM is designed to take advantage of high-speed transmission media, such as E3, SONET, and T3.

authentication In security, the verification of the identity of a person or a process. *See* AAA.

authorization In security, the determination of a user or devices rights in a network. *See* AAA.

auxiliary port A physical connector on a router that is designed to be used to allow a remote terminal, or PC with a terminal emulator, to access a router using an analog modem.

balanced hybrid A term that refers to a third general type of routing protocol algorithm, the other two being distance vector and link state. EIGRP is the only routing protocol that Cisco classifies as using a balanced hybrid algorithm.

Boolean AND A math operation performed to a pair of one-digit binary numbers. The result is another one-digit binary number. 1 AND 1 yields 1; all other combinations yield a 0.

BRI Basic Rate Interface. An ISDN interface composed of two bearer (B) channels and one data (D) channel for circuit-switched communication of voice, video, and data.

broadcast address An IP address in each subnet is considered to be the broadcast address for that subnet. It is the highest numerical value in the range of numbers for the subnet; the broadcast address cannot be assigned as an IP address to a computer. Packets sent to this address are delivered to all hosts in the subnet.

broadcast domain A set of all devices that receive broadcast frames originating from any device within the set. Devices in the same VLAN are in the same broadcast domain.

broadcast subnet When subnetting a Class A, B, or C network, two subnet numbers are "discouraged" from use; one of those two subnets is the broadcast subnet. It is the subnet number for which the subnet bits all have a value of binary 1.

bus A common physical signal path composed of wires or other media across which signals can be sent from one part of a computer to another. Also called a *highway.*

CDP Cisco Discovery Protocol. A media- and protocol-independent device-discovery protocol that runs on all Cisco-manufactured equipment, including routers, access servers, bridges, and switches. Using CDP, a device can advertise its existence to other devices and receive information about other devices on the same LAN or on the remote side of a WAN. Runs on all media that support SNAP headers, including LANs, Frame Relay, and ATM media.

CHAP Challenge Handshake Authentication Protocol. A security feature supported on lines using PPP encapsulation that prevents unauthorized access. CHAP does not itself prevent unauthorized access; it merely identifies the remote end. The router or access server then determines whether that user is allowed access.

CLI Command-line interface. An interface that enables the user to interact with the operating system by entering commands and optional arguments.

clock source The device to which the other devices on the link adjust their speed when using synchronous links.

codec Coder-decoder. An integrated circuit device that transforms analog voice signals into a digital bit stream and then transforms digital signals back into analog voice signals.

collision domain A set of network interface cards (NICs) for which a frame sent by one NIC could result in a collision with a frame sent by any other NIC in the same collision domain.

configuration mode Inside the Cisco IOS Software CLI, a user can move among various modes. Configuration mode enables the user to enter configuration commands but not any EXEC commands—for instance, the user can configure an IP address, but cannot show the status of any router features.

configuration register In Cisco routers, a 16-bit, user-configurable value that determines how the router functions during initialization. In software, the bit position is set by specifying a hexadecimal value using configuration commands.

console port A component of a router or switch through which commands are entered into a host.

convergence The time required for routers to react to changes in the network, removing bad routes and adding new, better routes so that the current best routes are in all the routers' routing tables.

CPE Customer premises equipment. Any equipment related to communications that is located at the customer site, as opposed to inside the telephone company's network.

CSMA/CD Carrier sense multiple access collision detect. A media-access mechanism in which devices ready to transmit data first check the channel for a carrier. If no carrier is sensed for a specific period of time, a device can transmit. If two devices transmit at once, a collision occurs and is detected by all colliding devices. This collision subsequently delays retransmissions from those devices for some random length of time.

CSU/DSU Data service unit/channel service unit. Used on digital links as an interface to the telephone company in the United States. Routers typically use a short cable from a serial interface to a DSU/CSU, which is attached to the line from the telco with a similar configuration at the other router on the other end of the link.

demarc The demarcation or separation point between carrier equipment and CPE.

Diffusing Update Algorithm (DUAL) The process by which EIGRP routers collectively calculate the routes to place into the routing tables.

Dijkstra Shortest Path First (SPF) algorithm Magic math used by link-state protocols, such as OSPF, when the routing table is calculated.

directed broadcast address Same thing as broadcast address.

distance vector The logic behind the behavior of some interior routing protocols, such as RIP and IGRP. Distance vector routing algorithms call for each router to send its entire routing table in each update, but only to its neighbors. Distance vector routing algorithms can be prone to routing loops but are computationally simpler than link-state routing algorithms. Also called *Bellman-Ford routing algorithm*.

DNS Domain Name System. A system used on the Internet for translating names of network nodes into addresses.

DSL Digital subscriber line. Public network technology that delivers high bandwidth over conventional copper wiring at limited distances. The most common types of DSL are ADSL, HDSL, SDSL, and VDSL. Because most DSL technologies do not use the complete bandwidth of the twisted pair, there is room remaining for a voice channel.

E1 Similar to a T1, but used in Europe. It uses a rate of 2.048 Mbps and 32 64-kbps channels.

enable mode Inside the Cisco IOS Software CLI, a user can move among various modes. Enable mode, also called enable EXEC mode, allows the user to use the most powerful and potentially disruptive commands on a router.

encapsulation The wrapping of data in a particular protocol header. For example, an IP packet could be encapsulated in an Ethernet header and trailer before being sent over an Ethernet.

encryption Applying a specific algorithm to data to alter the appearance of the data, making it incomprehensible to those who are not authorized to see the information.

error recovery The process of noticing when some transmitted data was not successfully received and resending the data until it is successfully received.

Ethernet A baseband LAN specification invented by Xerox Corporation and developed jointly by Xerox, Intel, and Digital Equipment Corporation. Ethernet networks use CSMA/CD and run over a variety of cable types.

exterior routing protocol A routing protocol designed for use between two different organizations. These typically are used between ISPs or between a company and an ISP. For example, a company would run BGP, an exterior routing protocol, between one of its routers and a router inside an ISP.

FCIP Fibre Channel over IP. A protocol for sending Fibre Channel protocols over an IP network.

Fibre Channel A technology for transmitting data between computer devices at data rates from 100 MBps to 400 MBps over optical fiber or copper. Fibre Channel is optimized for connecting servers to shared storage devices and for interconnecting storage controllers and drives.

filter Generally, a process or a device that screens network traffic for certain characteristics, such as source address, destination address, or protocol, and determines whether to forward or discard that traffic based on the established criteria.

firewall A device or a software package that separates more secure network components from less secure components, protecting the more secure network from inappropriate access.

Flash A type of permanent memory, implemented either with a EEPROM chip or with a PC card that can be easily removed. Routers use flash instead of disk drives for storing large files, particularly the IOS.

flow control The process of regulating the amount of data sent by a sending computer towards a receiving computer. Several flow control mechanisms exist, including TCP flow control which uses windowing.

forward To send a frame received in one interface out another interface, toward its ultimate destination.

four-wire circuit A line from the telco with four wires, composed of two twisted-pair wires. Each pair is used to send in one direction, so a four-wire circuit allows full-duplex communication.

Frame Relay An industry-standard, switched data link layer protocol that handles multiple virtual circuits using LAPF encapsulation between connected devices. Frame Relay is more efficient than X.25, the protocol for which it generally is considered a replacement.

frame A logical grouping of information sent as a data link layer unit over a transmission medium. Can also be called an *L2PDU*.

full mesh A term describing a network in which devices are organized in a mesh topology, with each network node having either a physical circuit or a virtual circuit connecting it to every other network node. A full mesh provides a great deal of redundancy, but because it can be prohibitively expensive to implement, it usually is reserved for network backbones.

hash A mathematical formula applied to some input value for which it is difficult to recreate the input value even if you know the results of the formula. Hashes are useful for transmission of passwords because, even if intercepted, the hashed representation of a password cannot easily be used to find the original password.

HDLC High-Level Data Link Control. A bit-oriented synchronous data link layer protocol that specifies a data encapsulation method on synchronous serial links using frame characters and checksums.

head end The upstream, transmit end of a CATV installation.

holddown A state into which a route is placed so that routers neither advertise the route nor accept advertisements about the route for a specific length of time (the holddown period). Holddown is used to flush bad information about a route from all routers in the network. A route typically is placed in holddown when a link in that route fails.

host address The IP address assigned to a network card on a computer.

host A computer system on a network. Similar to a node, except that host usually implies a computer system, whereas node generally applies to any networked system, including access servers and routers.

HTML Hypertext Markup Language. A simple hypertext document-formatting language that uses tags to indicate how a given part of a document should be interpreted by a viewing application, such as a web browser.

HTTP Hypertext Transfer Protocol. The protocol used by web browsers and web servers to transfer files, such as text and graphic files.

ICMP Internet Control Message Protocol. A network layer Internet protocol that reports errors and provides other information relevant to IP packet processing. Documented in RFC 792.

IEEE 802.2 An IEEE LAN protocol that specifies an implementation of the LLC sublayer of the data link layer. IEEE 802.2 handles errors, framing, flow control, and the network layer (Layer 3) service interface. Used in IEEE 802.3 and IEEE 802.5 LANs.

IEEE 802.3 An IEEE LAN protocol that specifies an implementation of the physical layer and the MAC sublayer of the data link layer. IEEE 802.3 uses CSMA/CD access at a variety of speeds over a variety of physical media.

IEEE Institute of Electrical and Electronics Engineers. A professional organization that develops communications and network standards, among other activities.

IGRP Interior Gateway Routing Protocol. Interior Gateway Protocol (IGP) developed by Cisco to address the issues associated with routing in large networks.

interior routing protocol A routing protocol designed for use within a single organization. For example, an entire company might choose the IGRP routing protocol, which is an interior routing protocol.

IOS Cisco operating system software that provides common functionality, scalability, and security for all Cisco products. Cisco IOS Software allows centralized, integrated, and automated installation and management of internetworks while ensuring support for a wide variety of protocols, media, services, and platforms.

IP Internet Protocol. The network layer protocol in the TCP/IP stack offering a connectionless internetwork service.

IP address A 32-bit address assigned to hosts using TCP/IP. Each address consists of a network number, an optional subnetwork number, and a host number. The network and subnetwork numbers together are used for routing, and the host number is used to address an individual host within the network or subnetwork.

IPX Internetwork Packet Exchange. A Novell NetWare network layer (Layer 3) protocol used for transferring data from servers to workstations. IPX is similar to IP and XNS.

iSCSI IP SCSI. A protocol for sending and receiving SCSI commands over an IP network, providing file-level access to shared storage devices.

ISDN Integrated Services Digital Network. A service offered by telephone companies that permits telephone networks to carry data, voice, and other source traffic.

ISL Inter-Switch Link. The Cisco proprietary VLAN trunking protocol.

ISO International Organization for Standardization. An international organization that is responsible for a wide range of standards, including those relevant to networking. The ISO developed the OSI reference model, a popular networking reference model.

L4PDU The data compiled by a Layer 4 protocol, including Layer 4 headers and encapsulated high-layer data, but not including lower-layer headers and trailers.

Layer 3 protocol A protocol that it has characteristics like OSI Layer 3, which defines logical addressing and routing. IP, IPX, and AppleTalk DDP are all Layer 3 protocols.

learn The process of discovering MAC addresses, and their relative location by looking at the source MAC address of all frames received by a bridge or switch.

link-state A type of routing protocol which sends full topology information about the network to all routers, so they all have a consistent view of the network topology and status. Link-state algorithms create a consistent view of the network and, therefore, are not prone to routing loops; however, they achieve this at the cost of relatively greater computational difficulty and more widespread traffic.

LLC Logical Link Control. The higher of the two data link layer sublayers defined by the IEEE. Synonymous with IEEE 802.2.

local loop A line from the premises of a telephone subscriber to the telephone company CO.

MAC Media Access Control. The lower of the two sublayers of the data link layer defined by the IEEE. Synonymous with IEEE 802.3 for Ethernet LANs.

MAC address A standardized data link layer address that is required for every device that connects to a LAN. Ethernet MAC addresses are 6 bytes long and are controlled by the IEEE. Also known as a *hardware address*, a *MAC layer address*, and a *physical address*.

metric A unit of measure used by routing protocol algorithms to determine the best pathway for traffic to use to reach a particular destination.

modem Modulator-demodulator. A device that converts digital and analog signals for the purpose of communicating over analog telephone lines. At the source, a modem converts digital signals to a form suitable for transmission over analog communication facilities. At the destination, the analog signals are returned to their digital form. Modems allow data to be transmitted over voice-grade telephone lines.

multimode A type of fiber-optic cabling with a larger core than single-mode cabling, allowing light to enter at multiple angles. Such cabling has lower bandwidth than single-mode fiber but requires a typically cheaper light source, such as an LED.

name server A server connected to a network that resolves network names into network addresses.

network A collection of computers, printers, routers, switches, and other devices that can communicate with each other over some transmission medium.

network number A number that uses dotted-decimal notation like IP addresses, but the number itself represents all hosts in a single Class A, B, or C IP network.

NVRAM Nonvolatile RAM. A type of random-access memory (RAM) that retains its contents when a unit is powered off.

OSI Open System Interconnection reference model. A network architectural model developed by the ISO. The model consists of seven layers, each of which specifies particular network functions, such as addressing, flow control, error control, encapsulation, and reliable message transfer. The OSI reference model is used universally as a method for teaching and understanding network functionality.

packet A logical grouping of information that includes the network layer header and encapsulated data.

PAP Password Authentication Protocol. An authentication protocol that allows Point-to-Point Protocol (PPP) peers to authenticate one another. Unlike the Challenge Handshake Authentication Protocol (CHAP), PAP passes the password and the host name or username in the clear (unencrypted).

partial mesh A network in which devices are organized in a mesh topology, with some network nodes organized in a full mesh but others that are connected only to one or two other nodes in the network. A partial mesh does not provide the level of redundancy of a full-mesh topology but is less expensive to implement. Partial-mesh topologies generally are used in the peripheral networks that connect to a fully meshed backbone.

PCM Pulse code modulation. A technique of encoding analog voice into a 64-kbps data stream by sampling with 8-bit resolution at a rate of 8000 times per second.

PDU Protocol data unit. An OSI term to refer generically to a grouping of information by a particular layer of the OSI mode. More specifically, an LxPDU would imply the data and headers as defined by Layer x.

ping Packet Internet groper. An Internet Control Message Protocol (ICMP) echo message and its reply; ping often is used in IP networks to test the reachability of a network device.

port number A field in a TCP or UDP header that identifies the application that either sent (source port) or should receive (destination port) the data inside the data segment.

PPP Point-to-Point Protocol. A protocol that provides router-to-router and host-to-network connections over synchronous and asynchronous circuits.

prefix notation A shorter way to write a subnet mask in which the number of binary 1s in the mask is simply written in decimal. For instance, /24 denotes the subnet mask with 24 binary 1 bits in the subnet mask. The number of bits of value binary 1 in the mask is considered to be the prefix.

PRI Primary Rate Interface. An Integrated Services Digital Network (ISDN) interface to primary rate access. Primary rate access consists of a single 64-kbps D channel plus 23 (T1) or 30 (E1) B channels for voice or data.

Protocol Type field A field in a LAN header that identifies the type of header that follows the LAN header. Includes the DIX Ethernet Type field, the IEEE 802.2 DSAP field, and the SNAP protocol Type field.

PSTN Public Switched Telephone Network. A general term referring to the variety of telephone networks and services in place worldwide. Sometimes called *POTS*.

PTT Post, telephone, and telegraph. A government agency that provides telephone services. PTTs exist in most areas outside of North America and provide both local and long-distance telephone services.

RAM Random-access memory. A type of volatile memory that can be read and written by a microprocessor.

RFC Request For Comments. A document used as the primary means for communicating information about the TCP/IP protocols. Some RFCs are designated by the Internet Architecture Board (IAB) as Internet standards, and others are informational. RFCs are available online from numerous sources, including www.rfc-editor.org/.

RIP Routing Information Protocol. An Interior Gateway Protocol (IGP) supplied with UNIX Berkeley Standard Distribution (BSD) systems. RIP is the most common IGP in the Internet and uses hop count as a routing metric.

RJ-45 A popular type of cabling connector used for Ethernet cabling. It is similar to the RJ-11 connector used for telephone wiring in homes in the United States. RJ-45 allows the connection of eight wires.

ROM Read-only memory. A type of nonvolatile memory that can be read but not written by the microprocessor.

routed protocol A protocol that can be routed by a router. A router must be capable of interpreting the logical internetwork as specified by that routed protocol. Examples of routed protocols include AppleTalk, DECnet, and IP.

routing protocol A protocol that accomplishes routing through the implementation of a specific routing algorithm. Examples of routing protocols include the Interior Gateway Routing Protocol (IGRP), the Open Shortest Path First (OSPF) protocol, and the Routing Information Protocol (RIP).

segment A term used in the TCP specification to describe a single transport layer unit of information. Can instead be called an *L4PDU*.

segmentation The process of breaking a large piece of data from an application into pieces appropriate in size to be sent through the network.

single-mode A type of fiber-optic cabling with a narrow core that allows light to enter only at a single angle. Such cabling has a higher bandwidth than multimode fiber but requires a light source with a narrow spectral width (such as a laser).

socket A software structure operating as a communications endpoint within a network device.

SONET Synchronous Optical Network. A standard format for transporting a wide range of digital telecommunications services over optical fiber. SONET is characterized by standard line rates, optical interfaces, and signal formats. SONET is a high-speed (up to 2.5 Gbps) synchronous network specification developed by Bellcore and designed to run on optical fiber. STS-1 is the basic building block of SONET. It was approved as an international standard in 1988.

star A method of connecting devices in which endpoints on a network are connected to a common central switch by point-to-point links.

storage router A device that sits between an IP network and storage devices, translating between disk IO protocols as they pass through non-IP and IP networks.

STP Shielded twisted pair. A two-pair wiring medium used in a variety of network implementations. Shielded twisted-pair cabling has a layer of shielded insulation to reduce electromagnetic interference (EMI). Can also refer to Spanning Tree Protocol, which is used to prevent bridging/switching loops.

subnet broadcast address Same thing as broadcast address.

subnet mask A 32-bit address mask used indicate the bits of an IP address that are being used for the subnet part of the address. Sometimes referred to simply as the mask.

subnet Subnets are subdivisions of a Class A, B, or C network, as configured by a network administrator. Subnets allow a single Class A, B, or C network to be used instead of multiple networks, and still allow for a large number of groups of IP addresses, as is required for efficient IP routing.

subnetting The process of subdividing a Class A, B, or C network and into smaller portions called subnets.

switch A network device that filters, forwards, and floods frames based on the destination address of each frame. The switch operates at the data link layer of the Open System Interconnections (OSI) reference model.

synchronous The imposition of time ordering on a bit stream. Practically, a device will try to use the same speed as another device on the other end of a serial link. However, by examining transitions between voltage states on the link, the device can notice slight variations in the speed on each end and can adjust its speed accordingly.

T1 A line from the telco that allows transmission of data at 1.544 Mbps.

TCP Transmission Control Protocol. A connection-oriented transport layer TCP/IP protocol that provides reliable data transmission.

TCP/IP Transmission Control Protocol/Internet Protocol. A common name for the suite of protocols developed by the U.S. Department of Defense in the 1970s to support the construction of worldwide internetworks. TCP and IP are the two best-known protocols in the suite.

telco A common abbreviation for telephone company.

Telnet The standard terminal emulation protocol in the TCP/IP protocol stack. Telnet is used for remote terminal connection, enabling users to log in to remote systems and use resources as if they were connected to a local system. Telnet is defined in RFC 854.

trace Short for traceroute. A program available on many systems that traces the path that a packet takes to a destination. It is used mostly to debug routing problems between hosts. A traceroute protocol also is defined in RFC 1393.

transparent bridge A device that forwards frames between LAN segments based on the destination MAC address. Transparent bridging is so named because the presence of bridges is transparent to network end nodes.

trunking Also called *VLAN trunking*. A method (using either Cisco's ISL protocol or the IEEE 802.1q protocol) to support multiple VLANs that have members on more than one switch.

twisted pair Transmission medium consisting of two insulated wires arranged in a regular spiral pattern. The wires can be shielded or unshielded. Twisted pair is common in telephony applications and in data networks.

UDP User Datagram Protocol. Connectionless transport layer protocol in the TCP/IP protocol stack. UDP is a simple protocol that exchanges datagrams without acknowledgments or guaranteed delivery.

update timer A timer used by a router to indicate when to send the next routing update.

user mode A mode of the user interface to a router or switch in which the user can type only nondisruptive EXEC commands, generally just to look at the current status, but not to change any operational settings.

UTP Unshielded twisted pair. A four-pair wire medium used in a variety of networks. UTP does not require the fixed spacing between connections that is necessary with coaxial-type connections. Five types of UTP cabling are commonly used: Category 1 through Category 5 cabling.

VLAN A group of devices on one or more LANs that are configured (using management software) so that they can communicate as if they were attached to the same wire, when, in fact, they are located on a number of different LAN segments. Because VLANs are based on logical instead of physical connections, they are extremely flexible.

VoIP Voice over IP. The capability to carry voice over an IP-based Internet. VoIP enables a router to carry voice traffic (for example, telephone calls and faxes) over an IP network.

well-known port A port number reserved for use by a particular application. The use of well-known ports allows a client to send a TCP or UDP segment to a server, to the correct destination port for that application.

windowing The term window represents the number of bytes that can be sent without receiving an acknowledgment. Windowing is the dynamic raising and lowering of the window to control the flow of data in a network.

WWW World Wide Web. A large client/server network of Internet servers providing hypertext and other services (based on HTML and HTTP) to terminals running client applications, such as a browser.

zero subnet When subnetting a Class A, B, or C network, two subnet numbers are "discouraged" from use; the zero subnet is one of these two subnets. It is the subnet number for which the subnet bits all have a value of binary 0.